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Marketing and Mobility. Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980

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Marketing and Mobility

Report of a panel of the

INTERAGENCY TASK FORCE ON MOTOR VEHICLE GOALS BEYOND 1980

March 1976

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16. Abstracts: This report documents an econometric model of automobile and travel demand. This model is designed to estimate the consumer response to changes in automobile price, fuel price, and fuel economy in specific automobile classes (small, mid-size and large) which may be brought about by Federal policies. These policies include automobile excise taxes and rebates based on fuel economy, mandatory fuel economy standard and motor fuel taxes. By combining this behavioral model with a simulation model of automobile manufacturer's behavior, it is possible to estimate the probable impact of these three policies. The marketing and mobility model produces estimates of automobile demand for each of three size classes, sales-weighted new car fuel economy, automobile fleet characteristics, vehicles miles traveled and automobile fuel consumption.

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Marketing and Mobility

Report of a panel of the

INTERAGENCY TASK FORCE ON MOTOR VEHICLE GOALS BEYOND 1980

March 1976

INTERIM REPORT

Prepared by

The Panel on

MARKETING AND MOBILITY

C. Difiglio, Federal Energy Administration
Chairman

This report was prepared under the supervision of the Marketing and Mobility Panel established for the Interagency Task Force for Motor Vehicle Goals Beyond 1980.

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NOTE:

The primary purpose of this Panel Report is to document a model of automobile and travel demand which has been designed to serve the specific needs of the Interagency Task Force for Motor Vehicle Goals. As such, this is a technical discussion which, at certain points, assumes that the reader is familiar with econometric terms. This was done to facilitate an accurate discussion of certain modeling issues. A glossary of these terms is provided.

MARKETING AND MOBILITY PANEL REPORT

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1.0 TASK FORCE STRUCTURE

On March 21, 1975, Secretary Rogers C. B. Morton, Chairman of the Energy Resources Council, requested that the Secretary of Transportation lead a joint Federal task force to examine long-range energy goals of the motor vehicle fleet, compatible with environmental, safety and economic objectives. The Task Force consists of representatives from the Federal Energy Administration, the Energy Research and Development Administration, the Environmental Protection Agency, the National Science Foundation and the Department of Transportation and others.

The Task Force was directed to:

1. Examine the present state of knowledge for motor vehicle emissions, noise, safety, damageability, fuel economy, performance and cost.

2. Relate the national goals of air quality, noise reduction, highway safety, vehicle damageability, and energy conservation to the characteristics of the

present and projected motor vehicle fleet, to the economy and to public health and mobility.

3. Determine feasible levels and timing for motor vehicle emission, noise, safety, damageability and fuel economy objective beyond 1980 and determine the process whereby these objectives could be established in a balanced manner.

4. Evaluate alternative policies, their benefits and costs and feasible implementation strategies to achieve national goals.

5. Provide for public hearings in carrying out its mission.

The period of time being considered is the decade beginning 1980. Representatives of more than 20 agencies of the U. S. Government constitute the membership of the panels.

Eight special panels within the Task Force were established to address major impact areas. These panels include Air

Quality; Noise and Health; Safety; Fuels and Materials Resources; Automotive Design; Automotive Manufacturing and Maintenance; Marketing and Mobility; National/Industry/Consumer Economics; and Alternative Implementation Strategies.

The Air Quality, Noise, and Health Panel will:

- Evaluate the effects of different levels of automotive emissions upon air quality in the various Air Quality Control Regions (AQCR).

- Assess the health and beneficial cost implications of the above air quality.

- Identify alternative methods for improving air quality and reducing noise including automotive inspection and maintenance strategies and assess their benefits.

The Safety Panel will:

- Evaluate the effects of different levels of vehicle safety characteristics upon highway accidents, injuries, deaths, vehicle damage.

- Assess the resulting social and economic benefits.

- Determine alternative methods of improving highway safety including automotive inspections and maintenance strategies, and assess their benefits.

The Fuels and Materials Resources Panel will:

- Determine the availability and costs of fuels in the 1980 and beyond time period.

- Determine the availability and costs of materials that may be used in automobile manufacturing.

The Automotive Design Panel will:

- Generate vehicle configurations and vehicle operating characteristics for a number of given vehicle requirement scenarios (based on existing and projected technology).

- Specify and describe automobile designs that will minimize fuel consumption for specified levels of emission and safety.

The Automotive Manufacturing and Maintenance Panel will:

- Determine industry requirements (lead times, labor, capital, material and energy) to manufacture and maintain projected fleets which incorporate selected fuel efficient vehicle configurations.

- Estimate vehicle purchase prices and maintenance costs for vehicles in projected fleet.

The Marketing and Mobility Panel will:

- Assess the level and structure of consumer automobile travel demand.

- Project the size and mix of automobile fleets based on consumer demand beyond 1980.

- Aggregate the effect of these projections upon fuel consumption, vehicle miles traveled (VMT), and patterns of automobile usage.

The National/Industrial/Consumer Economics Panel will:

- Project the level and rate of change of those National economic indicators which affect the automotive manufacturing industry and the consumer demand for and use of automobiles.

- Project the impact of alternative motor vehicle goals upon the automotive industry, the consumer, and the National economy.

The Alternative Implementation Strategies Panel will:

- Develop and evaluate alternative Federal strategies to accomplish the conceivably feasible motor vehicle designs.

The data made available by each of the several panels will be described comprehensively in a Panel Report, except for the last panel (Alternative Implementation Strategies) which will be included in the Task Force Report.

The reports of the panels will provide the data base for the Task Force Report. The latter will describe the analysis of realizable automotive design goals, their impacts on the consumer, and the economy and the alternatives for government actions to facilitate the design goals.

The Task Force analysis will compare a number of alternative automobile design scenarios. Each scenario represents a different compromise of competing considerations for reduced vehicle emissions and noise and enhanced safety and fuel economy. For each scenario, there will be a definition of strategies for implementing rational policies with respect to automobiles. The Motor Vehicle Goals Report will describe the merits and demerits of the several design alternatives and of the alternatives for government actions to facilitate realization of these alternatives.

The analysis of each design goal is shown as a sequence of steps in Figure I-1. Designs (for three sizes of automobile) implementing a particular design goal (such as maximum fuel economy, or safety, or lower emissions, or a combination) are described. These designs will change with time as technological capability progresses. The process by which that design would be

manufactured is then described and its manufacturing cost estimated. The third step is the establishment of sales price. The fourth step is the projection, as a time changing quantity, of the sales of the cars each year, the changed composition of the entire U. S. automotive fleet, and of the vehicle miles traveled by that U. S. fleet. The next step is the evaluation of safety and pollution impacts and the drain on the Nation's supply of fuel and materials. The bases for the estimates of impacts are the vehicle miles traveled and the design characteristics of the automobile fleet.

The final step, the "bottom line," is made by summing these data as the estimates of impacts as seen by the consumer, the automotive and materials industries, and the Nation's economy as a whole.

The step described by the last block of Figure I-1 is the comparative review of the several possible government actions required for the realization of the design goal, which may or may not be possible without government intervention of some kind.

FIGURE 2-1

3.0 MARKETING AND MOBILITY MODEL

3.1 FORECAST CONSTRAINTS

The structure of the Interagency Task Force for Motor Vehicle Goals Beyond 1980 dictates that the Marketing and Mobility Panel receive certain input variables and provide certain output variables. Thus, to a great extent, the Marketing and Mobility Model structure is predetermined by this data flow. While there is considerable latitude as to how to provide certain outputs, these outputs must be regarded as variables endogenous to the Marketing and Mobility Model and certain variables produced by other panels must be taken to be exogenous.

Tables 3-1 and 3-2 provide the specified input and output variables which constrain the model and their source or user panels. The input variables (Table 3-1) are most detailed with respect to automobile characteristics. A market classification system of small, mid-size, and large cars is required with average price and fuel economy variables specified for each class in each future year through 2000. The Task Force definition of these three size categories is based on a roominess index. The roominess index used is a sum of seven interior measurements:

TABLE 2-1

INPUTS TO MARKETING AND MOBILITY MODEL
(Each Variable Identified by Year for Each Year 1976 through 2000)

VARIABLE	SOURCE PANEL
o Average New Car Purchase Price of Small Cars	o Automotive Manufacturing o National, Industrial, Consumer Economics
o Average New Car Purchase Price of Mid-Size Cars	o National, Industrial, Consumer Economics
o Average New Car Purchase Price of Large Cars	o National, Industrial, Consumer Economics
o Average New Car Fuel Economy of Small Cars	o Automotive Design
o Average New Car Fuel Economy of Mid-Size Cars	o Automotive Design
o Average New Car Fuel Economy of Large Cars	o Automotive Design
o Fuel Price	o Fuels and Materials
o Index of Real Income (to be determined by Marketing and and Mobility Panel)	o National, Industrial, Consumer Economics
o Demographic Variable (to be determined by Marketing and Mobility Panel)	o National, Industrial, Consumer Economics

TABLE 2-2

OUTPUTS FROM MARKETING AND MOBILITY PANEL
(Each Variable Identified by Year for Each Year 1976 through 2000)

VARIABLE	USED PANEL
o Fuel Consumption o Automobile Diesel o Gasoline/91 RON/No Lead o Gasoline/98 RON/Leaded o Gasoline/91 RON/Leaded	o Fuels and Materials o National, Industrial, Consumer Economics
o Vehicle Miles Traveled	o National, Industrial Consumer Economics o Safety o Air Quality
o New Car Sales of Small Cars	o National, Industrial, Consumer Economics
o New Car Sales of Mid-Size Cars	o National, Industrial, Consumer Economics
o New Car Sales of Large Cars	o National, Industrial, Consumer Economics
o Total New Car Sales	o National, Industrial, Consumer Economics
o Average New Car Prices	o National, Industrial, Consumer Economics
o Scrappage by Car Type	o Fuels and Materials
o Various Fleet Characteristics	o Safety o Air Quality
o Total Automobiles in Operation	o Safety o Air Quality

- seat height, front
- head room, front
- head room, rear
- leg room, front
- leg room, rear
- shoulder room, front
- shoulder room, rear

In terms of this index three size classes are defined:

Class	Roominess Index
Small	≤ 264 inches
Mid-Size	265 inches - 274 inches
Large	≥ 275 inches

The specification of price and fuel economy averages for each class is necessary so as to trace the impact that alternative technologies and government policies may have on both the absolute prices for cars and on the relative prices between classes.

The behavioral model should indicate both:

- the impact on submarket demand caused by a change in price of that submarket, and
- the impact on submarket demand caused by a change in the price of another submarket.

Similarly, the behavioral model should estimate these two types of impact caused by changes in the fuel economy of each submarket. Variations of other automobile characteristics beyond price and fuel economy were left as optional inputs to the Marketing and Mobility Model should the Panel find it necessary and feasible to incorporate them.

The remaining input variables (Table 2-1) include fuel price and two or more economic and demographic variables that the Panel would itself specify. The fuel price variables represents an important policy instrument (fuel taxes) and is necessary to determine operating costs (with the fuel economy projection for each class of car). Other operating costs, such as expected repairs and maintenance, are also potential inputs which the Marketing and Mobility Model should be sensitive to.

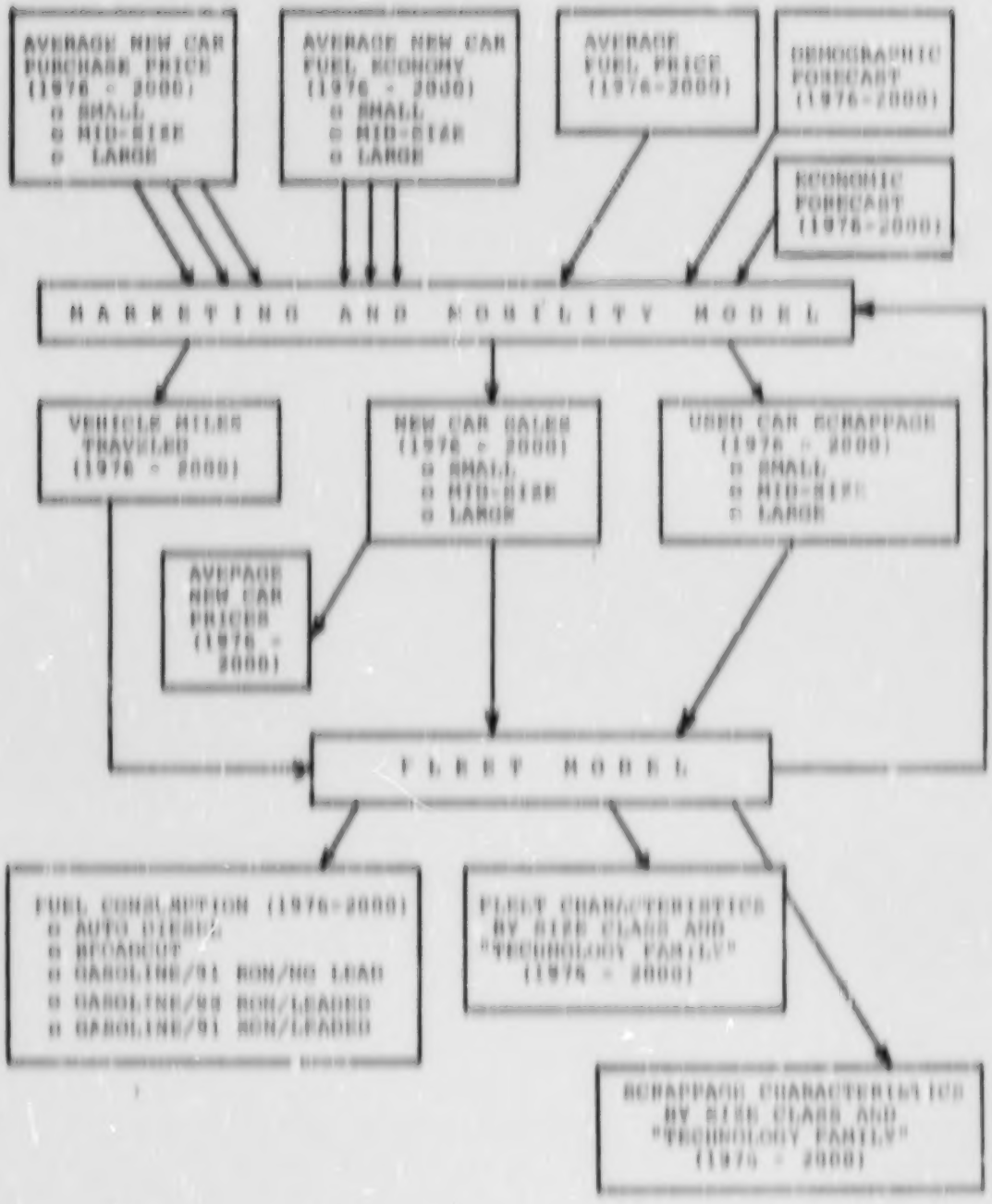
The format of the required output variables (Table 2-2) is determined by the needs of each user panel. The Fuels and Materials Panel requires fuel consumption estimates for five types of automotive fuels. Also the National, Industrial, Consumer Economics Panel requires total fuel consumption as a direct input for their activities. Vehicle miles traveled is a variable which must be estimated to determine fuel consumption but it is also required as a direct input for three panels: National, Industrial, Consumer Economics; Safety; and Air Quality. Similarly, all other variables in Table 2-2 are applied as intermediate variables in the process of estimating fuel consumption but also have a direct use by some other panel. The National, Industrial, Consumer Economics Panel requires new car sales for each class of car and sales-weighted average new car prices. The Fuels and Materials Panel requires estimated scrappage of cars so as to account for recoverable materials. Since different automobile design scenarios may involve different concentrations of recoverable materials, the scrappage estimate must be disaggregated by automobile type. In the context of the design scenarios used by the Task Force, an adequate materials accounting was achieved by identifying scrapped cars by their size class and their "technology family." "Technology families"

are classifications of cars into basic technology groups within each size class. This classification is provided by the Automotive Design Panel. Since the characteristics of a particular size class and "technology family" do not, by assumption, vary between years, all characteristics of the cars entering, remaining, or leaving the fleet can be identified by providing the distribution of cars in each size class and "technology family." Rather than separately identifying the material content of cars scrapped in any given year, the distribution of automobiles scrapped by size group and "technology family" is sufficient information with which to determine the recoverable materials associated with that year's scrappage. Likewise, an accounting of all automobile characteristics in the fleet (weight, crash-worthiness, etc.) is implied by the distribution of automobiles (by size group and "technology family") which remain in the fleet. Explicit indexing of each desired characteristic is avoided simply to reduce the amount of new input observations which must be manually entered into the Marketing and Mobility Model for each scenario.

Figure 2-1 shows schematically the input and output constraints on the (as yet unspecified) Marketing and Mobility Model. All inputs are shown to feed the model directly. However, model outputs are chained together whenever non-behavioral relationships are involved. For example, the fuel consumption estimate would not be directly produced by a behavioral model which forecasts automobile and travel demand but would be a consequence of those forecasts and the input automobile fuel economy. The output variables which are directly produced by behavioral relationships are vehicle miles traveled, new car sales by size class and used car scrappage by size class. The output variable, average new car price, is computed as a weighted average based on the estimated sales mix of cars by size class and the average new car purchase price for each size class specified as an input to the Marketing and Mobility Model. A fleet model is required to keep an accounting of the cars (by type) in the fleet and leaving the fleet, but this model itself contains no behavioral relationships so long as new car sales and scrappage

OVERALL STRUCTURE OF
MARKETING AND MOBILITY MODEL WITH
REQUIRED INPUTS AND OUTPUTS

FIGURE 2-1



are provided. The fleet model does, however, provide year to year feedback to the Marketing and Mobility Model.*

* This report does not document the fleet model employed since only exact, *a priori* relationships are involved.

2.2 FORECAST OBJECTIVES

Within the context outlined above, there is considerable latitude as to which variables to incorporate into forecasts and how they can be structured to determine the required output variables. The Task Force requirements essentially dictate development of a model of automobile and travel demand and, in particular, a model sensitive to the purchase cost, fuel economy, and fuel cost components of automobile travel. This model must also be sensitive to the relative costs of travel as determined by the fuel economy and purchase price of each market class (small, mid-size, and large). These relative costs are particularly critical in determining market shares by size class and in projecting average new car prices and fuel economies from the corresponding characteristics for each size class. The model structure should be oriented toward sensitivity to these input variables rather than explanation of historical statistics per se. While it is important to know how fuel cost changes will affect automobile and travel demand, it is of

secondary importance to know how certain other factors affect automobile demand. Consider, for example, the role of credit availability to new car purchasers. It may be valuable to use a measure of credit availability in order to reduce unexplained variation in historical automobile ownership data and to help improve upon the statistical properties of the parameters of the key input variables. However, it may not be appropriate to use such a variable to help forecast future automobile demand or ownership; it is not a policy instrument as far as the Task Force is concerned, and as an exogenous variable, it cannot be reliably forecasted into future periods any more easily than automobile demand itself can be forecasted. There is no point in using exogenous variables which cannot be substantially controlled through policy measures to help forecast the endogenous variables when the former are equally or more difficult to forecast than the latter. However, any exogenous variable may be useful to derive a more reliable estimate of the parameters for exogenous variables which can be forecast more reliably than automobile demand or for exogenous policy instruments to which the model is designed to be sensitive. Therefore, all variables are not equally useful, regardless of the contribution they may make in terms of decreasing unexplained variance (i.e., toward higher R^2s in the context of regression analysis). The procedures to be developed here constitute a long range forecasting model. Their

value lies in making as accurate projections of automobile ownership, use, and fuel consumption as can be achieved using statistical techniques with the available data. Many forces throughout the forecasting period will influence that accuracy. Economic theory, statistical techniques, and logic can help to identify some of the events and factors which will influence future automobile related behavior, and a realistic projection of this behavior should reflect these key events and factors--but only if they themselves can be reliably predicted or controlled. It is meaningless to base the model on forces which cannot be predicted or controlled with any greater reliability than automobile ownership, vehicle miles traveled, or gasoline consumption themselves.

The other side of the coin is that related elements which are predictable or controllable should be exploited by analytic models. Of all the factors bearing on automobile use twenty-five years hence, various demographic factors are the most certain. For example, all of the persons eligible to drive in 1990 were born by 1975; and forecasting the population of drivers in 2000 is mostly a matter of forecasting the fertility rate over the next ten years. Because of the relative predictability of population in the long run, and because of the

obvious *a priori* connection between population and automobile ownership, it seems plausible to structure automobile forecasts around a population baseline.

The model presented here is to be used in policy selection based on long-run *comparisons*. The most important question which it ultimately addresses is how much change will one policy effect relative to another. Prediction errors which distort the *relative* impacts of alternative policies are likely to be more damaging than errors of scale which distort all policy outcomes proportionally.

Complaints about lack of data are a common ingredient in the text of economic analyses. However, the deficiency in this

case derives from the lack of variation in past experience, not from failure to monitor and record behavior. Consequently, the necessity for extrapolation is inherent and not amenable to relief through additional data collection.

The projections to be made by this model would require forecasting as much as twenty-five years into the future. Twenty-five years ago imported cars were conversation pieces; today they account for about 20 percent of the new car market. In 1950 automobile air conditioners, power steering, and power brakes were almost unheard of and automatic transmissions were just being introduced; today the majority of new cars sold have power accessories and more than nine out of ten have automatic transmissions.

Twenty-five years earlier--1925--marked the beginning of automotive production and the widespread entry of the automobile into the American way of life. Twenty-five years before that the automobile was virtually non-existent. Predicting what will happen with respect to the automobile in the next twenty-five years is necessarily speculative and subject to forces which are impossible to predict.

Nevertheless, if any future state of the automobile market is to be selected as the most likely, it appears at this stage to be one which resembles the last twenty-five years, at least in the general role which the automobile plays in daily life. This is not to say that the design, propulsion system, size, fuel economy, power accessories, safety equipment, or anti-pollution technology will remain constant; on the contrary, significant changes in some of these areas are likely and will be introduced into the forecasting process by other members of the Task Force on Motor Vehicle Goals. Such changes would be input to the procedures of the Marketing and Mobility Panel.

In short, the extensive time frame of this forecast gives rise to a high degree of uncertainty. In our judgment, the likelihood of major shifts in the role of the automobile in the next twenty-five years is not as great as the perpetuation of the general function which the automobile currently serves. For this reason, the forecasting methodology to be developed will be based in part upon aspects of behavior which are observable from past experience and which are judged reasonably likely to pervade future experience.

2.3 FACTORS WHICH INFLUENCE AUTOMOBILE DEMAND

Automobile Ownership as A Derived Demand or as A Demand for A Final Product

The automobile is both a final product and an intermediate investment with which consume transportation. Because of this dual role, the motives for automobile ownership are a bit more complicated than for most other manufactured products. For some, the automobile is desired as a consumption good with little concern for the transportation services provided. Collectors of antique or classic cars are clear examples of such an outlook, but some degree of this view is often present in the ownership of specialty and luxury vehicles. Since automobile demand is, to a great extent, a derived demand, the characteristics of travel requirements and the total transportation environment should influence the characteristics of the automobiles demanded. Automobiles are clearly an attractive means of conveyance when compared to alternative modes, offering a good combination of comfort, flexibility, reliability, time, cost, and privacy. Consequently, most Americans regard the automobile as a basic need in order to get around, at least

for some part of their trip-making activity. However, the characteristics of automobiles demanded are not likely to be explained entirely by the transportation need fulfilled by them. For example, the desire to purchase a new car instead of a used car is probably only partly justified by a transportation need. Wykoff (66) notes two reasons that new cars are purchased by consumers:

- the esthetics, freshness, and prestige of new car ownership
- the reliability and relative certainty which attach to the conditions of new cars.

In terms of forecasting fuel demand, the distinction between new car and used car ownership is critically important since the impact of new car fuel economy improvements on gasoline consumption depends greatly on the ratio of new car purchases to used cars maintained in the fleet in an operating condition. Consequently, the adopted forecasting procedures produce estimates of both new car sales and automobile scrappage which are sensitive to the price and fuel economy characteristics

of new cars (by individual market class). In this way, the speed at which new car fuel economy characteristics become fleet characteristics can be estimated without assuming constant survivor rates. Also, since certain policies designed to increase the cost of (large) fuel inefficient cars will have different impacts on the scrappage of large versus small cars, it is important to estimate separately the scrappage of cars by each market class.

Importance of Income

Of all the socio-economic and demographic divisions which have been applied in order to identify patterns in national automobile ownership, none shows so strong a pattern as income (per capita, per household, or per family). The general nature of this relationship is shown in Figure 2-2, which is based on the Nationwide Personal Transportation Study (22). Very similar results were found when data from the Survey of Consumer Finances (53) and from Consumer Buying Indicators (56). The difference in automobile ownership

per population unit typically varies widely--often by a factor of 6--between the lowest and highest income groups tabulated.

In examining Figure 2-2 and comparable figures from other sources, another common characteristic stands out: the average number of cars owned per unit rises very rapidly as income increases throughout the low income groups, but this average flattens out at the high income end of the figure. This is suggestive of an income saturation effect. As spending units have more and more income, they are increasingly able and willing to buy more automobiles, but they do so at a rate which grows less than proportionally with income.

Figure 2-3 shows the percentage of households owning 0, 1, 2 and 3 or more cars. Households with incomes of $3,000 to $5,000* show a strong tendency toward single car ownership. As incomes increase to between $5,000 and $10,000, a tendency toward two car ownership swings into dominance. The region

*Income figures in this illustration are in terms of 1969-1970 dollars.

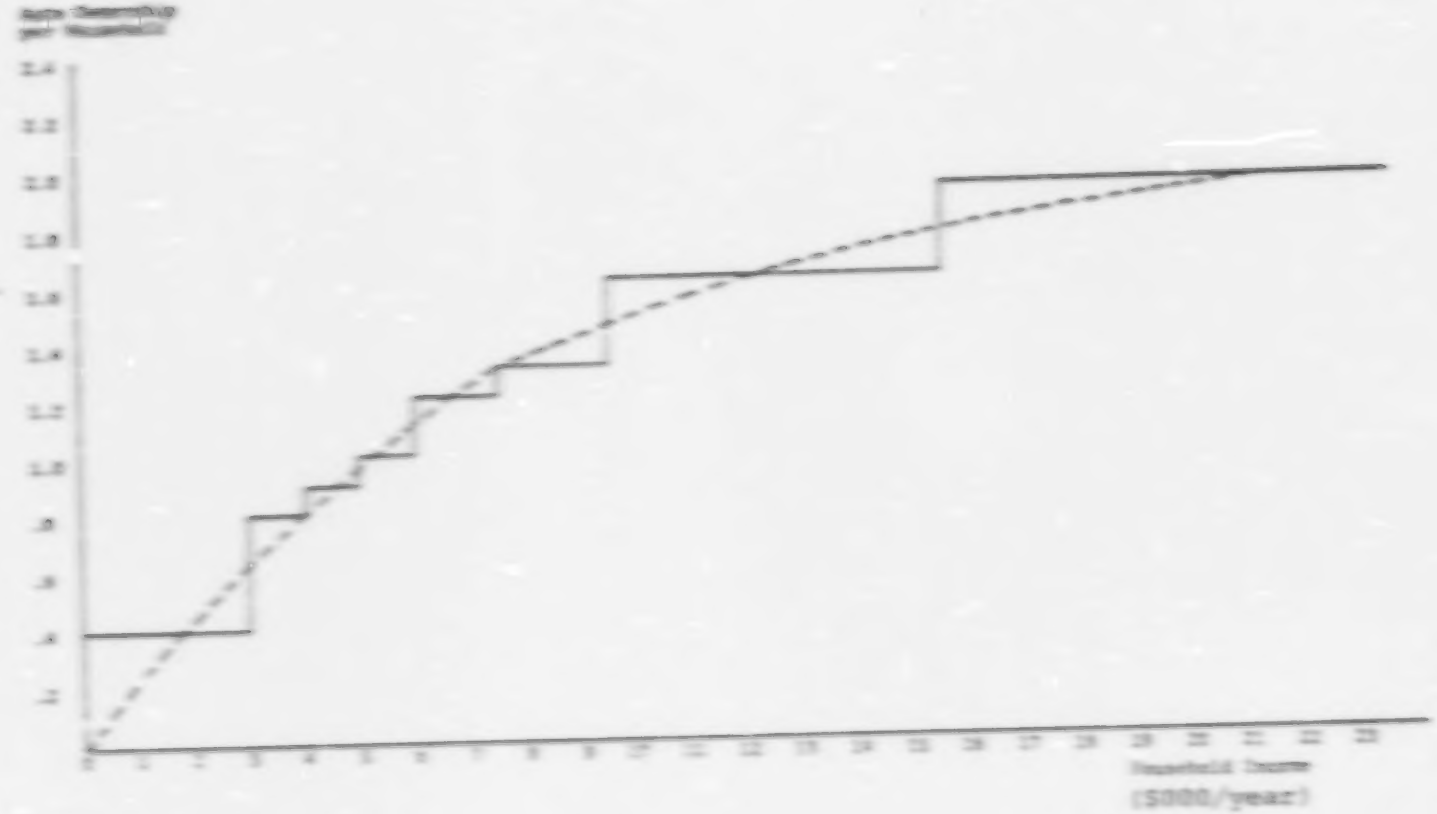


FIGURE 2-2.- AUTO OWNERSHIP PER HOUSEHOLD BY HOUSEHOLD INCOME (1969-70)

Source: U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, No. 11, December 1974, p. 22.

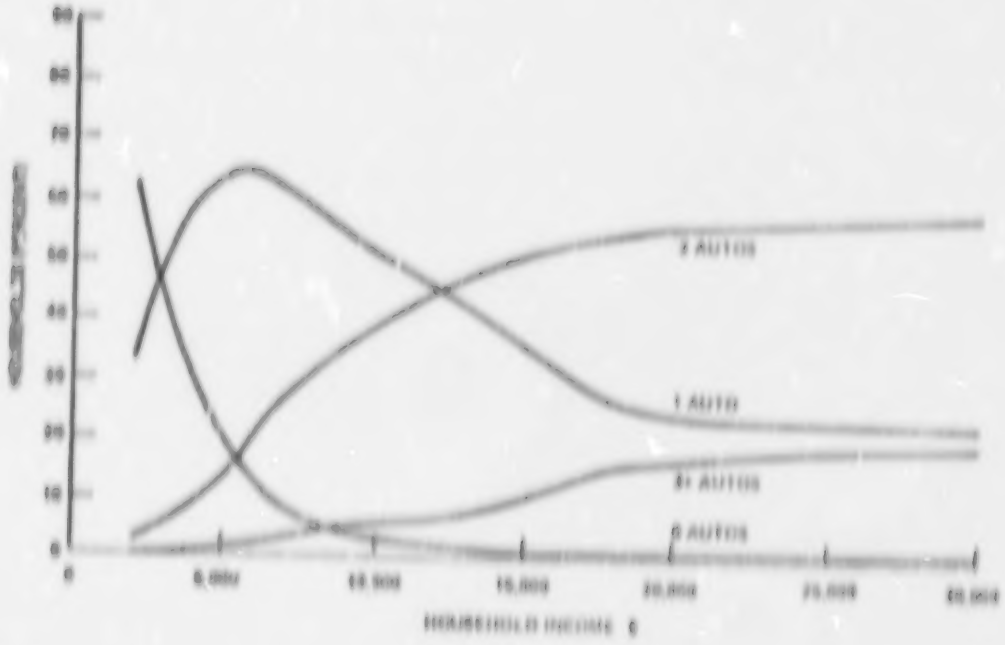


FIGURE 2-3: CAR OWNERSHIP VS. HOUSEHOLD INCOME (1969-1970)

Source: Taken from U.S. Department of Transportation, Federal Highway Administration, Office of Highway Planning, "Highway Travel Forecasts," November 1974, based originally on data from the Nationwide Personal Transportation Study, 1969-70, Federal Highway Administration.

between $12,000 and $16,000 marks the threshold of three-or-more car ownership, though even at the high end of the income scale, relatively few households (about 20 percent) seem to select this course of action. Even the two-car household percentage shows little growth as income moves beyond $20,000. These trends suggest that much of the growth in automobile ownership occurs as the population moves upward through the $1,000 to $12,000 income brackets, and that a relative plateau in automobile ownership is shown by households with incomes in excess of $20,000. That is, there comes a point when an additional car serves such a limited function that even the affluent are unwilling to pay the costs of owning and operating it. For example, it is possible to envision a natural saturation point of this sort corresponding to a situation where all household members have their own cars. Of course, there will always be some automobile collectors, users of specialized vehicles, and others who may wish to exceed such a saturation point. Somewhat more realistically, one might envision a saturation point corresponding to one vehicle per licensed driver, since there would generally be little use for additional vehicles per household beyond that point. Even this saturation point is unrealistically high, since many households, regardless of income, would still

choose to spend their income on items from which they drew greater utility than second, third, or fourth cars.

The above statistics on automobile ownership versus income indicate that the Marketing and Mobility Model should use household income as an explanatory variable, but that this factor should be less influential as income levels increase and be more powerful at lower income levels. Because the most well-behaved relationships observed relate income to automobile ownership rather than new or used car purchases (since these are irregular events) it is helpful to structure the new car purchase equation around the income versus automobile ownership relationship. Further, it would be valuable to take advantage of cross sectional data relating income and automobile ownership. This would tend to eliminate any secular trends which can plague time series regressions that involve income. Income tends to be correlated with time and any secular trends will also tend to be correlated with income. This can introduce multicolinearity bias when variables which measure these trends are not included in a regression relationship.

Using data from 1970 Consumer Buying Indicators (56) the following income versus automobile ownership relationship was developed:

Automobile ownership per household

$$= 0.01786 \text{ (income)}^{.4743}$$

$$R^2 = .983$$

Data from several other years were also tested to determine the stability of this relationship over time. Variations of both parameters were insignificant. This equation was used in the new car demand equation, as described.

Income can also have an impact on the class of vehicle purchased by families and individuals. The relationship of purchase behavior by class of vehicle to family income is shown in Tables 2-3 and 2-4. These tables are from a recent survey of new car purchasers and alternatively tabulate (1) the percent of automobiles in each income group that is represented by each of several market segments, and (2) the percent of each market segment that is purchased by members of the respective income classes. From Table 2-3 it can be seen that foreign economy cars account for the largest share among the market segments for all income groups up to the $40,000 level. However, the relative importance of these cars declines

TABLE 2-3. -TOTAL FAMILY INCOME OF RECENT CAR PURCHASERS BY MARKET SEGMENT

(percents)

Market Segment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.9	4.3	11.1	5.0	8.2	14.1	11.6	28.2	9.8	5.3	2.6	1.1	2.7	8.6	[illegible]
[illegible]	1.8	2.3	6.5	3.7	7.1	12.1	11.9	28.2	12.5	6.9	5.6	2.1	7.5	8.6	[illegible]
[illegible]	1.8	5.1	8.1	5.7	17.4	14.0	14.5	16.9	10.8	3.2	2.5	2.3	2.6	8.7	[illegible]
[illegible]	2.2	5.3	10.3	7.1	8.2	11.4	11.9	16.6	8.8	4.1	2.6	2.3	4.5	2.6	[illegible]
[illegible]	0.5	2.3	3.3	3.6	8.2	10.3	14.9	22.6	13.0	6.7	3.5	2.7	7.6	1.8	[illegible]
[illegible]	1.2	3.7	8.3	5.3	9.4	13.3	15.5	19.9	11.5	4.5	2.5	2.3	2.9	8.8	[illegible]
[illegible]	0.6	2.6	5.5	5.0	8.5	11.6	15.3	21.2	13.1	6.5	2.9	2.1	5.3	8.6	[illegible]
[illegible]	0.7	1.7	3.9	4.3	6.9	10.8	16.4	21.6	16.8	7.4	3.6	2.7	5.6	8.5	[illegible]
[illegible]	1.1	3.5	6.6	5.2	8.2	11.8	16.5	19.9	12.5	6.4	3.9	2.7	5.7	8.8	[illegible]
[illegible]	0.6	1.6	2.7	1.9	5.5	8.6	13.8	19.5	15.6	8.7	5.5	4.2	11.7	1.1	[illegible]
[illegible]	0.2	0.6	1.1	1.8	2.6	5.4	10.1	16.9	16.9	12.8	8.9	5.5	18.9	8.4	[illegible]
[illegible]	0.1	1.1	0.7	1.2	1.6	4.7	6.8	13.1	14.3	9.3	7.8	8.2	31.9	8.7	[illegible]
[illegible]	0.5	0.5	0.8	0.9	0.5	3.6	4.7	10.2	8.6	11.1	4.6	7.9	47.2	8.6	[illegible]
[illegible]	0.8	3.2	5.4	4.6	7.5	11.5	13.3	19.5	13.1	8.7	3.7	2.7	5.3	8.8	[illegible]
[illegible]	0.8	8.3	1.5	7.2	3.8	9.1	8.9	13.9	17.3	11.6	10.6	1.6	24.6	8.6	[illegible]

[illegible] may not add to total due to independent rounding.

Source: Computed from data purchased from Rogers National Research, Inc., Toledo, Ohio, June 1975.

TABLE 2-4. -SECREST SHARE OF MARKET - BY FAMILY INCOME - OF RECENT CAR PURCHASERS

(percents)

Market Segment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Percent Share of Sales
Subcompact	1.0	2.4	1.3	1.4	1.2	1.4	1.3	1.2	1.1	1.0	.7	.5	.6	1.2
Sporty Compact	2.7	4.3	5.2	3.3	3.7	4.3	3.9	2.6	2.8	2.1	3.6	2.4	2.2	3.1
Low Price Compact	11.9	10.7	9.4	6.7	8.5	9.9	6.0	4.8	4.0	7.9	3.3	3.9	2.5	5.4
Medium Price Compact	5.1	3.6	3.5	3.2	2.1	2.9	1.8	1.3	1.1	1.0	1.4	1.2	.8	1.7
Luxury Compact	3.3	10.4	3.0	4.3	5.4	5.1	5.4	5.6	4.6	3.8	4.4	4.1	3.4	4.7
Low Price Intermediate	9.3	10.4	8.5	6.7	11.5	8.9	8.4	8.0	6.4	4.6	4.1	2.9	2.2	7.2
Medium Price Intermediate	3.1	6.8	10.9	14.5	9.0	10.9	10.1	10.2	10.9	9.7	7.5	5.3	5.6	8.7
Intermediate Specialty	7.8	5.6	7.0	10.3	7.9	9.6	10.6	9.9	12.0	9.0	7.8	5.3	5.6	8.7
Low Price Standard	13.4	13.1	10.9	9.3	12.7	12.1	13.7	11.6	10.9	10.0	10.6	7.5	6.8	11.0
Medium Price Standard	8.7	4.8	6.0	7.8	6.4	8.6	11.8	12.6	15.5	16.6	14.5	18.2	15.4	12.8
Luxury Personal		.2	.5	.5	.7	.9	1.4	1.7	2.4	3.1	4.1	3.3	4.1	1.8
Luxury	.6	2.2	.2	.8	1.4	1.8	2.4	3.4	5.4	8.2	9.6	14.9	25.9	5.6
Luxury Specialty	1.3	.4		.4	.1	.6	.6	1.1	1.2	2.8	2.2	5.1	10.2	2.0
Foreign Economy	21.5	16.9	21.6	18.3	17.1	14.3	11.3	15.2	12.9	14.1	18.7	18.3	10.3	15.8
Other	.1	.2	.3	.2	.3	.6	.6	.6	1.0	1.2	1.5	1.6	5.7	1.1
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	
Percent Share of Total Market	.8	2.5	4.9	3.9	7.1	15.4	14.0	19.3	13.5	7.9	4.8	3.1	8.9	100

Source: Data purchased from Segura National Research, Inc., Toledo, Ohio, June 1975.

above the $10,000 level. Medium-price standards and luxury cars are positively correlated with income and exhibit the greatest relative growth in the share of each income group: the standards account for 4.8 percent of all automobiles purchased by the $1,000 to $5,000 group and 19.4 percent of automobiles purchased by the "over $40,000" category, while luxury accounts for 0.2 percent at the $5,001 to $7,500 level and 20.9 percent at the "over $40,000" level. The relative shares of the low-price compact and low-price intermediate both decline as the income level rises. The medium-price intermediate maintains a significant share (greater than 10 percent) for all income groups between $5,001 and $25,000, while the share of low-price standard remains relatively constant at 10 to 13 percent for all income groups except the "over $40,000."

Table 2-4 shows the median family income of purchasers of each market class with the low-price compacts representing the class associated with the lowest median income followed by the medium-priced compacts, subcompacts, and low-priced intermediates. At the top of the scale, in descending order, are the luxury specialty cars, luxury, other (than economy) foreign cars, and luxury personal. A classification of the makes included in each market segment is located in Table 2-5.

TABLE 2-5. -MARKET SEGMENT CLASSIFICATIONS

Subcompact	Low Price Standard
Astre	Chevrolet
Gremlin	Ford
Pinto	Plymouth
Vega	
Sporty Compact	Medium Price Standard
Camaro	Buick
Firebird	Chrysler
Monza 2+2	Dodge
Mustang II	Mercury
Skyhawk	Oldsmobile
Starfire	Pontiac
Low Price Compact	Luxury Personal
Dart	Riviera
Hornet	Thunderbird
Maverick	Toronado
Nova	
Valiant	
Medium Price Compact	Luxury
Apollo	Cadillac
Comet	Imperial
Omega	Lincoln Continental
Ventura	
Luxury Compact	Luxury Specialty
Granada	Eldorado
Monarch	Continental Mark IV
Low Price Intermediate	Foreign Economy
Chevelle	Audi 100LS
Fury	Audi Fox
Matador	Capri
Torino	Colt
Medium Price Intermediate	Datsun
Century	Toyota
Coronet	Volkswagen Dasher
Cutlass	Volkswagen Type 1
Grand AM	
Lemans	
Montego	
Intermediate Specialty	Other
Charger	Corvette
Cordoba	Mercedes Benz
Cougar	Porsche 911
Elite	Porsche 914-2.0 Litre
Grand Prix	Porsche 914-1.8 Litre
Monte Carlo	

Source: Rogers National Research, Inc. Toledo, Ohio.

The variation of market segment by income is less pronounced if the small, mid-size, and large classification systems are used. In Table 2-6, the segment shares from Table 2-4 are aggregated into the Task Force classification scheme. Between 40 and 50 percent car purchases are "small" for families with incomes between $7,500 and $25,000. Mid-size cars account for between 25 and 30 percent of the market for families with incomes between $5,000 and $25,000. Large car purchases represent less than 30 percent of the market for families with incomes below $20,001 but climb to 60 percent of the market for families with over $40,000 income.

The stability of these income versus market share relationships over the near term and long term future is highly uncertain. In the near term, an increased supply of small and intermediate luxury cars may well attract higher income purchasers. Also, as the status value of large cars diminishes, the income versus size relationship would be expected to be less strong. In the long term, demographic factors will tend to diminish the importance of the income versus size pattern. Income and age tend to be correlated. Since the older purchaser is probably more committed to the large car per se, the current pattern may actually be reflecting an age preference. As younger purchasers become older with high incomes, it is possible

Source: Computed from data furnished from Region National Research Inc., Toledo, Ohio, June 1975

| Region | | |

that they would prefer smaller cars over large cars. The increased availability of small cars with luxury characteristics should provide ample opportunity for this type of purchaser to purchase more amenity per car without necessarily buying a larger car.

Because of the likely temporal instability of the income vs. automobile size distribution currently observed (Table 2-6) by the use of income to help determine market shares will receive a lower priority than either:

- the use of income to determine total automobile ownership and purchase behavior.
- the use of relative purchase prices and fuel economies between market classes to determine market shares.

Importance of Credit Availability

Since most new car purchasers use some type of financing, automobile interest rates have a significant effect on the cost of automobile ownership. This was well established by Suits (50) and Hamburger (26) in their econometric studies of automobile demand. Suits' price variable is defined in

terms of the average monthly payment for a new car. This average monthly payment is strongly influenced by credit conditions. Suits determined that the credit condition component was so important that, if not included, the price elasticity of demand became +.40 (irrational) instead of -.98 with the credit variable included. Hamburger used the AA bond rate as a separate variable in a quarterly stock adjustment model finding that their maximum effect is achieved in 4 to 6 months. Hamburger estimates a price elasticity of -1.17 and an interest rate elasticity of -.85.

While credit availability is an important variable for explaining automobile demand and for short term demand forecasting, it is not easy to forecast this variable over the long term. Credit is a cyclical variable strongly tied to economic conditions and the policies of the Federal Reserve Board. While macroeconomic econometric forecasting models generally estimate some interest variable, these forecasts are for the short term and would maintain little variance if extended over the time frame required by the Task Force. Consequently, credit availability is not a particularly useful

variable for the Marketing and Mobility Model except insofar as it may help improve the parameter estimates of other variables which influence automobile demand.

Importance of Geographic Factors

Three levels of geographic aggregation were considered: metropolitan versus non-metropolitan areas, urban versus rural locations and by census region. This analysis was based on the 1960 and 1970 Censuses of Housing (56), which permitted the three types of geographical comparisons used. The census tabulates the number of occupied housing units (or households) for the various categories by the number of automobiles available--none, one, two, and three or more. The total number of automobiles owned (or "available") for each area was calculated by multiplying the number of households in each automobile availability category by the respective number of cars (0, 1, 2) and then summing the products. A problem arises in the "three or more cars" category since there are no data on the distribution of automobile ownership for greater-than-three-car households. We estimate the number of automobiles in this block by using

TABLE 2-7. -AUTOMOBILE OWNERSHIP - SUMMARY OF FINDINGS

Ownership Categories[a]	Year and Ownership Basis	Source	Variation in Ownership (percents)
Metropolitan/Non-metropolitan			
SMSA vs. Non-SMSA	1970-H	1970 Census of Housing	0.2
SMSA vs. Non-SMSA	1960-H	1960 Census of Housing	4.0
SMSA vs. Non-SMSA	1969-H	NPTS	0.3
SMSA vs. Non-SMSA	1970-H	Consus, CPR, Series P-65 and P-23	0.1
SMSA vs. Non-SMSA	1970-P	1970 Census of Housing	5.1
SMSA vs. Non-SMSA	1960-P	1960 Census of Housing	2.5
Central City vs. Suburbs	1970-H	1970 Census of Housing	60.2
Central City vs. Suburbs	1960-H	1960 Census of Housing	61.8
Central City vs. Suburbs	1970-H	Census CPR, Series P-65 and P-23	61.7
Central City vs. Suburbs	1970-P	1970 Census of Housing	23.2
Central City vs. Suburbs	1960-P	1960 Census of Housing	21.6
Urban/Rural			
Urban vs. Rural	1970-H	1970 Census of Housing	9.5
Urban vs. Rural	1960-H	1960 Census of Housing	17.5
Urban vs. Rural	1970-P	1970 Census of Housing	7.8
Urban vs. Rural	1960-P	1960 Census of Housing	8.9
Geographic Regions (Census)			
Highest (Mtn) vs. Lowest (Mid. At.)	1970-H	1970 Census of Housing	33.1
Highest (Mtn) vs. Lowest (Mid. At.)	1960-H	1960 Census of Housing	30.6
Highest (Pac.) vs. Lowest (Mid. At.)	1970-P	1970 Census of Housing	31.9
Highest (Pac.) vs. Lowest (So.Cen.)	1960-P	1960 Census of Housing	40.4
Availability of Rapid Transit			
Rapid Transit vs. No Rapid Transit	1970-H	1970 Census of Housing	11.6
Rapid Transit vs. No Rapid Transit	1960-H	1960 Census of Housing	9.7
Rapid Transit vs. No Rapid Transit	1970-H	1970 Census of Housing	3.6
Rapid Transit vs. No Rapid Transit	1960-H	1960 Census of Housing	6.5

H = Household Basis; P = Population Basis; CPR = Current Population Reports; NPTS = Nationwide Personal Transportation Study.

[a]*Underlined item represents category with the higher ownership.*

a factor of 1.1, a factor which takes into account the existence of households owning four or more cars. This factor is uniformly applied to each ownership category and used for both the 1960 and 1970 censuses. Justification for utilizing this factor can be seen by a comparison of the total automobile stock estimated from the census data with the estimated total number of cars in operation by R. L. Polk and Company:

Total Automobiles Owned
(thousands)

	Estimated from Census	Polk
1970	78,303	80,449
1960	54,497	57,101
percent change (1960-1970)	43.7	40.9

The level of automobiles is only a few percentage points below the Polk estimates which we should expect since we are estimating only automobiles owned by households, therefore excluding commercial and Government vehicles.

A summary of the statistics derived from the census data is shown in Table 3-8. On the basis of automobiles per household

TABLE 2-8.—AUTOMOBILE AVAILABILITY BY RACE OF HOUSEHOLDER AND BY SPANISH ORIGIN: 1970 AND 1975

(Numbers in thousands. Households as of March. Based on sample interviews of persons in the civilian noninstitutional population)

Year and automobile availability	All households	White	Black and other	Spanish origin
1975				
Total households	71,120	62,954	8,166	3,991
Percent	100.0	100.0	100.0	100.0
No automobile	8,744	6,772	1,972	1,000
Percent	12.3	10.8	24.1	25.1
1 automobile	28,284	24,966	3,318	1,600
Percent	39.8	39.7	40.6	40.1
2 automobiles	23,966	21,344	2,622	1,055
Percent	33.7	33.9	32.1	26.4
3 automobiles	7,126	6,437	689	252
Percent	10.0	10.2	8.4	6.3
4 automobiles	2,000	1,835	165	84
Percent	2.8	2.9	2.0	2.1
5 automobiles	1,000	600	400	0
Percent	1.4	1.0	4.9	0.0
1970				
Total households	63,401	56,245	7,156	2,992
Percent	100.0	100.0	100.0	100.0
No automobile	8,744	6,772	1,972	1,000
Percent	13.8	12.0	27.6	33.4
1 automobile	28,284	24,966	3,318	1,600
Percent	44.6	44.4	46.4	53.5
2 automobiles	23,966	21,344	2,622	1,055
Percent	37.8	37.9	36.6	35.3
3 automobiles	2,407	2,163	244	337
Percent	3.8	3.8	3.4	11.3

Source: Compiled from U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-60, No. 104.

the suburban area average in 1970 was 40.2 percent higher than the average for central cities and 16.0 percent higher than that for non-metropolitan areas. Based on the number of automobiles per person, the average in the suburbs was 23.2 and 12.7 percent higher than the averages for central cities and non-metropolitan areas, respectively. The growth in ownership over the period 1960 to 1970 for central city and suburban area households was about equal--19.8 and 19.1 percent, respectively. Household ownership in non-SMSAs increased by 17.3 percent for the same period. As stated earlier, there is virtually no difference in automobile ownership between metropolitan areas and non-metropolitan places, either on a household or per capita basis.

Another data source which results in similar conclusions is the census' Current Population Reports, Series P-65 (56). This source, which gives by place of residence the percent of households owning cars, together with a special census study on the number of households by place of residence, presents a profile of automobile ownership in 1970 (see Table 2-9). Ownership per non-SMSA household is only 0.7 percent higher than the average for SMSA households, while

TABLE 2-9. HOUSEHOLD AUTOMOBILE OWNERSHIP BY PLACE OF RESIDENCE METROPOLITAN VS. NON-METROPOLITAN AREAS - 1970

	Number of Households (thousands)	Number of Automobiles (thousands)	Automobiles per Household
Total SMSA	41,188	46,871	1.138
Central City	19,783	18,090	.914
Suburban Areas	21,405	28,521	1.332
Outside SMSA	21,688	24,859	1.146
Total, All Areas[a]	62,876	71,722	1.141

[a]*Data may not add to total due to independent rounding.*

Sources: Number of households from U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-28, No. 31, 1971; and number of automobiles computed from Current Population Reports, Series P-65, No. 33, 1970.

within the metropolitan area, the suburban average is 45.7 percent higher than that for the central cities. Analysis of data in the Nationwide Personal Transportation Study (22) which provides us with only an SMSA/non-SMSA split, also confirms that there is essentially no difference in automobile ownership between the two areas. These data are shown in Table 2-10.

The Bureau of Census' Current Population Reports Series P-65, and the Survey Research Center's Survey of Consumer Finances provide historical data on the percentage of households owning none, one, two, and three or more cars, for each of several place-of-residence categories. These data are shown in Tables 2-11 and 2-12. That the propensity of households to own an automobile is highest in the suburban areas can be seen by examination of data for 1972, the most recent year available in the census P-65 series. 87.3 percent of all households in the suburbs owned at least one car, compared to 81.5 percent for non-metropolitan areas and 66.4 percent for the central cities. This point is further accentuated when we look at the multiple-car households. 38.7 percent of suburban households owned two or more cars compared to 29.8 percent for non-metropolitan areas and 21.0 percent for the central

TABLE 2-16. HOUSEHOLD AUTOMOBILE OWNERSHIP BY PLACE OF RESIDENCE METROPOLITAN VS. NON-METROPOLITAN AREAS - 1969-1970

	Number of Households (millions)	Number of Automobiles[a] (thousands)	Automobiles per Household
All SMSAs	41.5	47,871	1.154
All Non-SMSAs[b]	21.0	24,292	1.157
Total, All Areas	62.5	72,163	1.155

[a] *Employed same method of estimation as utilized in Census of Housing data. See text.*

[b] *Source data is presented for SMSAs and all areas only. Non-SMSAs assumed to be the difference between the two.*

Source: Computed from U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 11, 1971, pp. 14 and 16.

TABLE 2-11.--HOUSEHOLD AUTOMOBILE OWNERSHIP BY PLACE OF RESIDENCE METROPOLITAN VS. NON-METROPOLITAN AREAS - 1960-1972

(percent of households in each group)

Household Ownership and Place of Residence	Jan. 1960 . . . Jan. 1967	July 1968	July 1969	July 1970	July 1971	July 1972
Metropolitan Areas						
1 Car	55.5 . . . 51.0	49.8	48.0	47.3	47.0	47.1
2 Cars	33.6	35.0	35.7	36.5	36.5	36.7
3 or More Cars	34.2	4.0	4.2	5.0	5.0	5.2
None	11.1 . . . 14.2	11.3	12.1	11.2	11.5	10.9
Central Cities						
1 Car	52.5 . . . 49.0	48.0	46.5	44.3	43.8	43.4
2 Cars	9.7	37.1	38.2	38.3	37.8	37.5
3 or More Cars	10.9	2.5	2.8	3.4	3.6	3.5
None	17.8 . . . 22.1	12.4	12.8	14.0	14.5	15.6
Suburban Rings						
1 Car	60.7 . . . 55.4	51.2	50.4	49.4	49.4	48.8
2 Cars	31.3	39.7	39.3	39.0	39.4	39.6
3 or More Cars	32.0	5.2	5.8	6.4	6.1	5.7
None	8.0 . . . 12.6	11.9	11.8	12.2	12.1	12.7
Non-Metropolitan Areas						
1 Car	61.0 . . . 58.8	55.2	55.8	56.0	55.1	53.7
2 Cars	18.7	31.6	31.5	31.8	31.6	31.5
3 or More Cars	6.5	3.8	4.2	4.2	4.2	3.5
None	20.1 . . . 17.9	19.5	17.6	17.8	18.8	16.6
All Areas						
1 Car	56.6 . . . 53.5	51.3	50.6	50.3	50.0	49.3
2 Cars	26.4	35.2	34.8	34.7	35.0	34.6
3 or More Cars	35.1	3.8	4.2	4.7	4.8	5.0
None	15.0 . . . 11.4	11.6	10.4	10.4	10.0	10.5

Source: U.S. Department of Commerce, Bureau of the Census, Current Population Reports, "Consumer Buying Indicators," Series P-65, Nos. 18, 28, 33, 39, and 44.

TABLE 2-12.- FAMILY AUTOMOBILE OWNERSHIP BY PLACE OF RESIDENCE METROPOLITAN VS. NON-METROPOLITAN AREAS - 1961-1970

Place of Residence	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
	Percentage of Families that Own at least One Car									
Central Cities of 12 Largest SMSAs	51	44	56	54	57	56	54	58	55	62
Central Cities of other SMSAs	68	70	81	80	77	77	73	70	67	66
Suburban Areas of 12 Largest SMSAs	86	85	90	83	90	86	85	89	91	91
Suburban Areas of other SMSAs	80	84	86	86	88	92	87	90	88	89
Adjacent Areas of SMSAs	78	77	86	84	85	85	86	86	86	86
Outlying Areas of SMSAs	77	75	75	75	76	75	76	76	77	85
All Families	74		80	78	79	79	78	79	79	82
	Percentage of Families that Own Two or More Cars									
Central Cities of 12 Largest SMSAs	6	7	8	14	10	11	8	10	11	10
Central Cities of other SMSAs	10	11	24	24	23	24	22	21	23	27
Suburban Areas of 12 Largest SMSAs	17	16	28	25	29	28	26	27	28	46
Suburban Areas of other SMSAs	26	22	27	25	25	27	24	26	29	25
Adjacent Areas of SMSAs	16	15	25	24	26	28	27	26	29	29
Outlying Areas of SMSAs	14	11	15	15	16	16	20	21	20	20
All Families	15		22	22	24	25	25	26	27	29

Source: Survey Research Center, Institute for Social Research, University of Michigan, Survey of Consumer Finances, several years.

cities. In the suburbs 7.7 percent of the households owned three or more cars while the non-metropolitan and central city groups accounted for 5.3 and 3.5 percent respectively. Another source of information, though more limited than those mentioned previously, is the study by Lansing and Hendricks (35). Their results, shown in Table 22, once again illustrate the same pattern of automobile ownership.

Data on purchases from the census P-65 series also reveal the leading position of suburbia with regard to new cars. Purchases per 100 households over the five year period of 1968 to 1972 amounted to 79.2 for suburban areas, 56.1 for non-metropolitan areas and 51.7 for central cities.

Another set of relevant statistics is the distribution of all automobiles owned by households in the various areas. These estimates are shown in Table 2-14 and indicate that about two-thirds of all automobiles are owned by metropolitan area inhabitants with suburban area residents representing about 40 percent of total automobiles.

The relative preference of market classes of new cars by place of residence is shown in Table 2-15. This recent survey of new purchases shows that foreign economy cars are the

TABLE 2-13 --FAMILY AUTOMOBILE OWNERSHIP BY PLACE OF RESIDENCE
METROPOLITAN AREAS

(percent of families in each area)

Number of Cars Owned by Family	Old Central Cities of 11 Largest SMSAs	New Central Cities of 11 Largest SMSAs	Smaller Central Cities	All Suburban Areas
One	38	41	48	49
Two or More	8	11	32	47
None	54	16	20	4

Source: John B. Lansing and Gary Hendricks, Automobile Ownership and Residential Density, Survey Research Center, University of Michigan, June 1967, p. 16.

TABLE 2-14: DISTRIBUTION OF AUTOMOBILES OWNED BY HOUSEHOLDS BY PLACE OF RESIDENCE METROPOLITAN VS. NON-METROPOLITAN AREAS

(percents)

	Census of Housing: 1960	Census of Housing 1970	NPTS 1969-1970[a]	Census' CPR	
				1970[a]	1971
Metropolitan Areas	63.2	69.1	66.3	65.4	64.8
Central Cities	29.0	27.9	NA	25.4	24.5
Suburban Areas	34.2	41.2	NA	40.0	40.3
Non-Metropolitan Areas	36.8	30.9	33.7	34.6	35.1
All Areas	100.0	100.0	100.0	100.0	100.0

CPR = Current Population Reports
NPTS = Nationwide Personal Transportation Study

[a]*Estimated by Jack Faucett Associates based on source data and methodology explained in the text.*

Sources: U.S. Department of Commerce, Bureau of the Census, Census of Housing, 1960 and 1970; Current Population Reports, Series P-60, Nos. 38 and 40, and Series P-25, No. 311 and U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 11.

TABLE 3-15. SEGMENT SHARE OF MARKET - BY LOCATION OF RESIDENCE
(percents)

Segment of Make Purchased	Metropolitan City	Suburban Community	Small Town, Rural City	Farming Area	Percent of Total Sales
Subcompact	1.1	1.5	1.5	1.0	1.3
Sporty Compact	5.5	5.0	2.9	2.5	3.1
Low Price Compact	6.0	6.4	5.0	6.1	5.4
Medium Price Compact	1.6	1.5	2.0	1.6	1.7
Luxury Compact	4.0	4.0	4.7	3.2	4.7
Low Price Intermediate	7.1	6.7	7.2	10.1	7.2
Medium Price Intermediate	10.2	10.1	8.7	8.4	9.5
Intermediate Specialty	6.0	6.0	5.1	10.0	6.7
Low Price Standard	8.1	9.0	13.1	21.9	11.0
Medium Price Standard	12.1	11.7	14.0	13.2	12.5
Luxury Personal	2.0	2.0	1.7	1.6	1.8
Luxury	5.6	6.2	4.7	5.0	5.5
Luxury Specialty	2.5	1.0	1.7	1.5	2.0
Foreign Economy	24.0	27.0	21.0	12.5	22.0
Other	1.6	1.6	1.0	.6	1.3
Total	100	100	100	100	
Percent Share of Total Market	22.5	35.0	33.7	8.4	100

Source: Data purchased from Rogers National Research, Inc. Toledo, Ohio, June 1974.

largest segment of vehicles bought in all places except farming areas, where the low-price standard is the leader. Significant variation by place of residence takes place in only these two vehicle classes. The low-price standard car shows the greatest variation with 21.9 percent of all farming area automobiles being of this type as compared to only 9.3 percent in the suburban community. The opposite pattern holds for foreign economy cars: 27.0 percent of suburban automobiles are of this type compared to 12.5 percent of farming area automobiles. All of the other vehicle classes vary by only 3 percentage points or less according to place of residence.

Automobile ownership data by urban and rural places of residence from the Census of Housing are summarized in Table 2-16. On the basis of households, the rural average ownership is about 9 percent higher than the urban average. However, on a population basis, the difference is very small. Over time, it appears that urban residents have maintained a higher growth in ownership than inhabitants of rural areas--from 1960 to 1970 urban household ownership increased 21.5 percent while ownership by rural households rose 18.0 percent.

TABLE 3-14.--AUTOMOBILE AVAILABILITY BY PLACE OF RESIDENCE
URBAN VS. RURAL AREAS - 1960 and 1970

	Number of Households (thousands)	[illegible]	Automobiles Available (thousands)	[illegible]	Persons per Household	Automobiles per Household	Automobiles per Person
Urban							
1970	47,567	75.0	57,383	75.3	3.0	1.206	.402
1960	38,320	72.3	38,069	69.7	3.2	.993	.310
% change	24.1	-	50.7	-	-6.2	21.5	29.7
Rural							
1970	15,878	25.0	20,920	26.7	3.3	1.318	.399
1960	14,704	27.7	16,428	30.1	3.6	1.117	.310
% change	8.0	-	27.3	-	-8.3	18.0	29.7
All Areas							
1970	63,445	100.0	78,303	100.0	3.1	1.234	.398
1960	53,024	100.0	54,497	100.0	3.3	1.028	.312
% change	19.7	-	43.7	-	-6.1	20.0	27.6

Source: Computed from U.S. Department of Commerce, Bureau of the Census, Census of Housing, 1960 and 1970.

Regional differences in automobile ownership patterns were explored using the nine census regional divisions. Census of Housing data show that on a household basis the Mountain region has the highest average ownership, about 11 percent higher than the Middle Atlantic region, representing the lowest average. The differential between the highest and lowest regions is the same on a population basis, about 15 percent, but the Pacific region accounts for the top spot while the Middle Atlantic remains at the bottom. Ownership patterns for the remaining six regions are quite uniform, as they all fall within five percent of the national average, on either a household or population basis. Ownership data by region are shown in Table 2-17. There also is evidence that the gap between the high and low regions is diminishing. From 1960 to 1970 the gap was reduced from 19 to 11 percent on a household basis and 40 to 15 percent on a population basis.

Another source of information is the Census' Current Population Reports, Series P-65 (58). Data are presented by region on the percentage of households owning none, one, two, and three or more cars as shown in Table 2-18. These data illustrate the high automobile ownership levels of the

TABLE 2-17 -AUTOMOBILE AVAILABILITY BY GEOGRAPHIC REGION 1960 and 1970

Region		Number of Households (thousands)	Percent of Total	Number of Automobiles Available (thousands)	Percent of Total	Persons per Household	Automobiles per Household	Automobiles per Person
New England	1970	3665	5.7	4429	5.7	3.1	1.215	.392
	1960	3139	5.9	3159	5.8	3.3	1.011	.306
	% change	17.0	-	39.6	-	-6.1	20.2	28.1
Middle Atlantic	1970	13857	18.7	13406	15.8	3.1	1.048	.338
	1960	10486	19.6	9164	16.8	3.2	.881	.276
	% change	11.8	-	16.4	-	-3.1	19.0	22.5
East North Central	1970	14381	19.5	15522	18.8	3.1	1.114	.362
	1960	10711	20.1	11319	20.7	3.3	1.057	.320
	% change	15.8	-	37.1	-	-5.8	10.3	22.5
West North Central	1970	5154	8.1	6527	8.3	3.1	1.266	.408
	1960	4668	8.8	5841	8.3	3.2	1.081	.339
	% change	10.4	-	39.3	-	-3.1	17.1	20.7
South Atlantic	1970	8838	11.8	11670	14.8	3.1	1.237	.350
	1960	7267	13.7	7282	13.2	3.5	.991	.283
	% change	29.9	-	82.7	-	-11.4	24.8	41.0
East South Central	1970	3668	5.1	3696	4.8	3.2	1.214	.378
	1960	3307	6.2	3077	5.6	3.6	.930	.258
	% change	13.0	-	32.9	-	-11.1	30.5	46.9
West South Central	1970	5952	8.4	7496	9.8	3.3	1.201	.364
	1960	4935	8.8	5255	9.5	3.4	1.062	.312
	% change	20.6	-	37.0	-	-3.9	21.8	20.1
Mountain	1970	3518	4.8	5519	6.3	3.1	1.561	.496
	1960	1976	5.7	2437	6.5	3.4	1.228	.363
	% change	77.4	-	84.7	-	-8.9	33.5	36.6
Pacific	1970	8651	13.6	11233	15.1	3.0	1.368	.456
	1960	6645	12.5	7682	14.5	3.3	1.156	.349
	% change	30.2	-	50.3	-	-9.2	33.5	30.1
All Regions	1970	63667	100.0	76303	100.0	3.1	1.199	.386
	1960	53024	100.0	53497	100.0	3.3	1.009	.312
	% change	19.7	-	33.7	-	-6.1	18.9	27.6

Source: U.S. Department of Commerce, Bureau of the Census; Census of Housing: 1960 and 1970.

TABLE 2-18.--HOUSEHOLD AUTOMOBILE OWNERSHIP BY GEOGRAPHIC REGION, 1972

(percent of households in each category)

Region	Owning at Least One Automobile	Owning No Automobiles	Owning One Automobile	Owning Two Automobiles	Owning Three or More Automobiles
New England	80.7	19.3	53.4	22.5	4.8
Middle Atlantic	70.8	29.2	45.0	21.4	4.4
East North Central	82.8	17.2	48.4	27.3	6.1
West North Central	85.1	15.0	54.4	23.6	7.0
South Atlantic	78.3	21.7	47.1	25.5	5.7
East South Central	78.7	21.3	47.6	26.1	5.0
West South Central	83.1	17.0	54.6	23.5	4.9
Mountain	87.3	12.7	56.1	24.9	6.3
Pacific	81.8	18.2	48.9	25.2	6.7
All Areas	79.3	20.5	49.3	24.6	5.6

Source: U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-65, No. 66.

Mountain region, and also reveal that both the West North Central and East North Central regions rank ahead of the Pacific region. At the low end of the automobile ownership scale is, once again, the Middle Atlantic region.

Relative growth rates in automobile ownership by regions can be estimated from both the Census of Housing and the P-65 series data. Table 2-19 presents four sets of rank orders of growth in ownership by region. The four ordering categories are growth in household ownership and population ownership from the Census of Housing, and the growth in the percent of households owning at least one car and the percent owning two or more cars from the P-65 series. This table clearly shows that the East South Central and South Atlantic regions have experienced the greatest relative growth in automobile ownership since 1960, while the Pacific and Mountain regions--areas having the highest average ownership --have undergone the least amount of growth.

The key findings of the above analysis are:

- There is no significant variation in ownership between metropolitan and non-metropolitan areas as defined by the census.

TABLE 2-19.--RANK ORDER OF RATE OF GROWTH IN AUTOMOBILE OWNERSHIP BY GEOGRAPHIC REGION

Region	Census of Housing 1960 - 1970		Census P-65 Series 1960 - 1972	
	Household Basis	Population Basis	Percent of Households Owning at Least One Automobile	Percent of Households Owning Two or More Automobiles
New England	4	4	8	6
Middle Atlantic	5	5	6	3
East North Central	6	6	4	5
West North Central	7	8	3	4
South Atlantic	2	2	1	2
East South Central	1	1	2	1
West South Central	3	3	5	7
Mountain	9	7	7	8
Pacific	8	9	9	9

Source: Compiled from U.S. Department of Commerce, Bureau of the Census, Census of Housing, 1960 and 1970, _____, Current Population Reports, Series P-65, Nos. 33 and 60.

- Within the metropolitan area there is a distinct difference in automobile ownership patterns of people residing in the central cities and those of people in suburban areas. Suburban ownership is about 40 percent higher on a household basis and 33 percent higher on a population basis. These relative percentages have remained virtually constant over time so that the respective growth in ownership has been about the same for both areas.

- Rural automobile ownership is slightly higher than urban on a household basis, but is similar on a population basis.

- The maximum range of variation by geographic regions (nine census regional divisions) is about 33 percent on both a household and population basis, with the Mountain and Pacific regions at the top of the scale and the Middle Atlantic region at the bottom. The six remaining regions are all within a few percentage points of the national average. Furthermore, these regional differences appear to be decreasing over time.

Although there are variations of automobile ownership among the specific geographic categories examined, there is insufficient variation to justify developing a regionally disaggregate model of automobile and travel demand.

Importance of Public Transit

Public transit is often cited as an important alternative to urban automotive travel and the future supply of public transit service in urban areas would seem to be an important variable for forecasting automobile ownership and automobile travel. Since improvement in public transit supply can affect automobile ownership only by diverting automobile travel, the evidence on vehicle miles traveled (VMT) impacts is critical. Several detailed urban area travel demand modeling studies have already yielded substantial evidence regarding the relationship between automobile travel and transit demand. These studies will be reviewed below in Section 2.5 (Factors Which Determine VMT). The material in this section will be limited to data regarding the impact that rapid transit availability has on automobile ownership in urban areas. However, anticipating Section 2.5, both types of evidence yield consistent conclusions.

Overall, metropolitan areas with rapid transit systems show lower automobile ownership, most notably in the New York City region. To determine the extent of this difference, we examined ownership characteristics of cities with rapid transit versus all other areas of the country. The areas which had rapid transit in 1970 include the following SMSAs: New York City, Boston, Chicago, Cleveland, Newark, and Philadelphia. Based on Census of Housing data, and excluding New York City, areas without rapid transit systems average 14 percent higher ownership than the transit cities on a household basis, and less than 4 percent on a population basis, as illustrated in Table 2-20. New York City was excluded from this comparison because it has much lower automobile ownership than other areas (about 40 percent lower), and we were interested in determining whether similar characteristics could be found for the other cities with transit. If New York is included with the transit cities, it dominates the averages and overshadows the pattern shown by the other five transit cities.

The above analysis indicates that transit cities have a slightly different automobile ownership profile than the rest of the nation, and that New York City has a very different pattern--only about 60 percent of the national

average. Between 1971 and 2000, however, the fraction of the population living in New York City is expected to change by only 0.2 percent (61), so that relatively little additional forecast accuracy would be gained by attempting to isolate this component of the national average.

In order to test the amount of potential error introduced by using an aggregate automobile demand model which does not consider public transit availability or geographic differences in automobile ownership (discussed above) a comparison was made between projections of the total automotive fleet based upon the public transit and geographic differences and others based on aggregate averages. It was found that projected shifts in population with respect to cities with transit availability and to other geographic categories would have minimal bearing on automobile ownership projections. Using separate detailed population forecasts for each of the various geographic categories, we estimated what the automobile stock would be in some future year. We then estimated the automobile stock by simply using aggregated nationwide data for automobiles per capita and projected population. Comparing the two methods of projection showed virtually no difference between them (Table 2-21). This suggests that little additional accuracy would be realized by including these

TABLE 2-28.- AUTOMOBILE AVAILABILITY
CITIES WITH RAPID TRANSIT SYSTEMS VS. ALL OTHER AREAS
1960 AND 1970

	Number of Households	Percent of Total	Number of Automobiles Available (thousands)	Percent of Total	Persons per Household	Automobiles per Household	Automobiles per Person
Rapid Transit Cities[1]							
1970	5726	9.7	6449	8.6	2.9	1.126	.390
1960	4984	9.7	4667	8.9	3.2	.935	.292
% change	15.5	–	38.4	–	-8.6	20.8	33.7
All Other Areas							
1970	53611	90.3	68654	91.4	3.2	1.281	.400
1960	48425	90.3	47625	91.1	3.3	1.029	.312
% change	11.3	–	44.8	–	-3.0	24.5	28.0
All Areas[2]							
1970	59368	100.0	75103	100.0	3.2	1.266	.396
1960	53409	100.0	52292	100.0	3.3	1.017	.309
% change	11.2	–	43.7	–	-3.0	24.5	28.2

[1] Includes Boston, Chicago, Cleveland, Newark and Philadelphia SMSAs. New York City is excluded.
[2] Includes New York City.

TABLE 2-21. - ALTERNATIVE METHODS OF PROJECTING AUTOMOBILE OWNERSHIP

Projection Year	Detailed Ownership Categories	Difference Between Aggregate and Stratified Projections
2000	Central City, Suburbs, Non-SMSA[a]	0.5%
2000	Central City, Suburbs, Non-SMSA[b]	1.5%
1990	Urban, Rural	0.0%
1990	Nine Census Regions	0.5%
2000	Rapid Transit Cities, Non-Transit Areas	1.5%

[a]Based on a high Central City population projection.
[b]Based on a low Central City population projection.

Sources: Population forecasts based on data in U.S. Department of Commerce, Bureau of the Census, Population Estimates and Projections, Series P-25, No. 519 and No. 601, work performed by the Population Division, U.S. Bureau of the Census, for the Commission on Population Growth and the American Future, Research Reports, Vol. V, Population Distribution and Policy, "Regional Metropolitan Projections," Chapter 7, Part I, 1972; U.S. Department of Transportation, The 1972 National Highway Needs Report, Part II, 1972, and U.S. Water Resources Council, 1972 OBERS Projections, Vol. 5, "Standard Metropolitan Statistical Areas." For existing auto ownership data is found in other tables in this section.

geographic elements in forecasting procedures, especially given the additional data assembly and structural complication which would be required to include them.

Additional factors must be considered to determine the impact of substantial changes in public transit supply. That discussion will be provided below in Section 2.5 using the evidence provided by urban travel demand models and certain UMTA demonstration projects.

Age

Like income, age seems closely tied to automobile ownership profiles. Both the overall automobile ownership pattern and the patterns of ownership by class of automobile show a distinct correspondence with the age of the head of household. Major demographic forces, such as the postwar surge in the fertility rate and recent declines in that rate lead to a projected future population distribution, by age, which varies from the distribution now in evidence. As illustrated in Table 2-22, the fraction of the population falling into fairly broad age categories will in some instances change by more than 20 percent between 1971 and 1990. Given distinct differences in automobile

ownership patterns by age of owner, and given that a significant shift in the composition, by age, of the population is projected during the forecast period, it seems reasonable to consider the role which consumer ages play in determining the level and type of automobiles owned.

Recent data on automobile ownership by age of head of household are shown in Table 2-21. As apparent from the columns to the right of the table, the number of cars per household generally increases with the age of the head of household, up to age 55, at which point it starts to decline. Family size is obviously a factor in this pattern since the household head age group which corresponds to families with driving age children, namely heads of 35 to 55 years of age, show the highest automobile ownership. They also show distinctly higher multiple car ownership per household.

Much less clear a trend is evident in terms of new car purchasing patterns by age. Table 2-24 shows the trend in the number of new and used cars purchased by age of head of household. Except for the 55 and over age group, there is relatively uniform pattern in the number of new cars purchased

TABLE B-33 CHANGE IN POPULATION AGE COMPOSITION
(Families and Unrelated Individuals)

Age of head or Individual	1971	1990[a]	Percent Change: 1971 to 1990
Under 35 years	9.1	6.8	-25.3
35 to 44 years	36.5	45.0	+23.3
45 to 64 years	35.0	27.6	-21.1
65 years and over	19.4	20.6	+6.2

[a]Series E

Source: U.S. Bureau of the Census, Current Population Reports, Series P-23, No. 47, "Illustrative Projections of Money Income Size Distributions for Families and Unrelated Individuals," 1974.

TABLE 2-23. - AUTOMOBILE OWNERSHIP BY AGE OF HEAD OF HOUSEHOLD
Fall 1975

Age of Head	Percent of Households Owning:			Number of Cars per 100 Households	Number of Motor Vehicles per 100 Households
	One or More Cars	Two or More Cars	Three or More Cars		
Under 25 years	84.7	27.3	2.3	117	125
25 - 29 years	85.9	31.8	2.0	123	135
30 - 34 years	87.0	35.9	2.2	127	142
35 - 44 years	88.9	45.6	6.6	147	164
45 - 54 years	87.3	48.3	12.3	160	174
55 - 64 years	82.9	34.7	6.9	132	144
65 years and over	61.6	12.0	1.5	77	84

Source: Bureau of the Census, 1973 Survey of Purchases and Ownership, selected data published in preliminary release, 1974.

TABLE 2-24. - AUTOMOBILE PURCHASES BY AGE OF HEAD OF HOUSEHOLD

Age of Head	New Car Purchases per 100 Households	Used Car Purchases per 100 Households
Under 25 years	15.0	35.9
25 - 29 years	15.0	25.9
30 - 34 years	13.3	21.8
35 - 44 years	14.1	23.9
45 - 54 years	15.1	19.1
55 - 64 years	11.8	12.9
65 years and older	6.3	5.2

Source: Bureau of the Census, 1972 Survey of Purchases and Ownership, selected data published in preliminary release, 1974.

per 100 households. Purchases of used cars, by contrast, decline markedly with the age of the head of household.

Purchase behavior by class of vehicle is also closely tied to age. The results of a recent survey of new car purchasers, tabulated by age group and vehicle class, are shown in Table 2-25. These data show that foreign economy cars are the single most popular category of new automobiles purchased by persons in every age group under 40 years old. Other vehicle classes which appeal to the under 30 buyer are the sporty compacts, intermediate specialties, and medium priced intermediates. The low and medium priced standards grow in relative importance for persons of age 30 to 39 years and for persons over 40 they become the predominant vehicle bought. The foreign economy cars maintain a significant share up to the 50 to 54 age bracket and then tail off while the medium price intermediate share is consistent over all age groups. The luxury share accounts for a moderate and relatively constant share throughout ages 40 to 64, but then jumps to the third leading category (after low and medium price standards) for persons 65 and over. Likewise, the share of the low price compacts increases significantly for this age group.

TABLE 2-15 -HIGHEST SHARE OF MARKET - BY AGE OF RECENT CAR PURCHASER

Segment of Make Purchased	Under 20	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65 and Over	Percent Share of Sales
Subcompact	1.7	1.9	1.8	1.1	1.1	.9	.9	.8	1.0	1.0	.6	1.3
Sporty Compact	10.7	6.1	4.6	1.8	1.7	1.1	1.3	1.3	1.3	.6	.2	3.1
Low Price Compact	5.1	4.7	4.1	4.7	5.0	4.4	4.7	5.7	6.9	7.2	10.3	5.6
Medium Price Compact	1.8	1.8	1.7	1.9	2.1	1.8	1.8	1.8	2.2	2.6	3.2	1.7
Luxury Compact	1.0	1.7	4.7	6.4	4.7	4.9	4.7	5.8	4.4	3.5	3.4	4.7
Low Price Intermediate	1.8	4.7	4.7	7.7	6.5	6.7	6.9	6.7	6.3	7.6	7.5	7.2
Medium Price Intermediate	6.0	9.7	11.0	9.9	9.4	8.5	9.3	10.3	11.9	11.1	10.0	9.9
Intermediate Specialty	9.3	11.2	11.3	11.7	10.1	10.3	7.2	6.1	6.7	5.9	3.6	8.7
Low Price Standard	.7	1.2	4.7	6.3	14.3	15.3	15.4	15.3	17.7	15.4	14.3	11.9
Medium Price Standard	.5	1.0	3.0	5.2	11.9	17.5	16.4	17.1	17.3	12.7	10.3	10.9
Luxury Personal	.4	.9	1.8	2.7	3.2	3.0	3.4	3.4	3.4	1.9	1.4	1.9
Luxury		.2	1.0	1.4	3.3	7.0	7.2	8.6	7.7	7.3	11.8	5.0
Luxury Specialty		.2	.7	1.0	2.7	2.4	2.8	3.7	2.9	1.9	1.9	2.0
Foreign Economy	39.6	47.1	38.7	27.9	20.1	17.1	14.7	14.9	8.3	8.2	4.8	22.8
Other	.4	1.3	1.3	1.8	1.9	1.7	1.3	1.3	1.7	.9	.7	1.3
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Percent Share of Total Market	7.7	11.7	12.4	9.4	8.3	7.9	8.8	11.3	8.7	7.0	6.7	100.0

Source: Data furnished from Urgens National Research, Inc., Toledo, Ohio, June 1971.

Alternatively Table J-26 shows the age of recent car purchases by market segment. Examination of the median age of the purchasers of each market segment reveals that sporty compacts are bought by the youngest automobile buyers followed closely by foreign economy cars and subcompacts. Segments associated with the oldest median age of buyer are, in descending order, luxury, medium-price standard, low-price standard, and luxury specialty.

Age and Income

As noted earlier, some of the differences in automobile ownership by age of head of household may be attributed to variations in family size. Similarly, much of the variation in the type of car purchased may be attributed to income. Table J-27 illustrates automobile ownership by income quartile and by age of head of household. The variation within any quartile is relatively small compared to the variation between income quartiles. This suggests that much of the observed pattern in ownership by age of head may be explained by variations in income: older heads of households are generally more affluent than younger heads, and the apparent

TABLE 2-26 AGE OF RECENT CAR PURCHASER - BY MARKET SEGMENT

(percentage)

Market Segment	Under 25	25-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65 and Over	Total, All Ages	Median Age (Years)
Subcompact	7.3	19.6	20.7	11.1	7.9	6.5	6.9	8.4	9.2	3.1	3.6	100.0	31.5
Sporty Compact	8.8	27.7	21.2	10.4	6.3	4.8	5.6	4.6	4.6	1.9	1.1	100.0	28.9
Low Price Compact	2.6	8.6	9.6	8.5	7.9	7.2	9.1	15.8	11.3	9.7	16.3	100.0	47.3
Medium Price Compact	3.2	10.6	10.3	7.1	6.9	7.3	9.2	9.4	11.1	10.5	16.5	100.0	47.8
Luxury Compact	1.8	8.8	10.3	12.6	7.7	8.7	9.3	12.6	7.7	.97	6.8	100.0	41.7
Low Price Intermediate	3.8	10.8	12.3	9.8	7.9	6.5	10.9	11.3	10.4	7.8	11.3	100.0	45.1
Medium Price Intermediate	2.9	12.2	15.4	9.6	7.6	8.3	9.1	10.7	8.7	7.1	8.4	100.0	42.2
Intermediate Specialty	3.3	16.3	17.9	12.5	9.3	10.3	8.1	8.7	6.4	3.5	4.6	100.0	38.5
Low Price Standard	5.2	7.7	9.3	7.1	8.9	9.9	12.5	14.3	13.9	11.6	14.6	100.0	51.6
Medium Price Standard	5.3	7.7	7.6	6.9	8.7	11.6	12.6	14.5	12.9	11.1	16.4	100.0	52.3
Luxury Personal	5.6	6.3	10.6	10.7	9.7	9.3	12.6	13.7	12.1	7.7	7.3	100.0	48.3
Luxury	5.3	7.7	7.3	5.7	6.3	10.1	13.3	16.3	14.8	11.8	14.8	100.0	52.8
Luxury Specialty	5.3	7.7	6.3	7.7	11.6	12.2	13.7	16.6	13.4	10.5	8.4	100.0	49.6
Foreign Economy	5.5	22.5	22.5	12.9	7.7	7.1	6.7	7.6	4.3	2.5	2.2	100.0	38.6
Other	3.2	17.6	16.1	10.9	10.7	8.5	8.2	9.3	7.4	3.2	5.8	100.0	39.3

*Does may not add to total due to independent rounding.

Source: Tabulated from data purchased from Polaris National Research, Inc., Toledo, Ohio, June 1975.

TABLE 3-27 - AUTOMOBILE OWNERSHIP BY INCOME QUARTILE AND AGE OF HEAD OF HOUSEHOLD

(number of cars owned per 100 households)

Age of Head	Income Quartile			
	Lowest	Second Lowest	Second Highest	Highest
Under 25 years	82	117	133	184
25 - 29 years	65	107	136	157
30 - 34 years	83	106	136	155
35 - 44 years	88	122	144	184
45 - 54 years	92	112	156	211
55 - 64 years	76	108	145	194
65 years and over	53	95	130	156

Source: *Bureau of the Census, 1972 Survey of Purchases and Ownership, selected data published in preliminary release, 1975.*

differences in automobile ownership by age may be largely a reflection of income. This point is made somewhat more forcefully by the data in Table 2-28, reflecting ownership in 1960 to 1961. There, automobile ownership is seen generally to decrease slightly with the age of the household head within any single income group, while the increase in automobile ownership rises sharply with income within each age group.

Because of the relationship between age and income, and the greater variation with income when the two can be isolated, income was chosen in preference to the age of head of household as the key determinant of automobile ownership.

Age, per se, may play a larger role in influencing the choice of class of cars than it does in the level of automobile ownership. However, there is little basis for projecting such a relationship into the future. The behavior of the current middle-aged population may not be archtypal of the behavior in 1990 to 2000 of those currently under thirty. Today's middle-aged population grew up in an age where relatively large

| | | |

cars were the dominant product offerings. Today's youth have been weaned on imports and subcompacts. Shifts such as these in the individual's history of automobile ownership could create significant changes in the profiles we observe today. With the increased consumer awareness of fuel economy, today's young automobile purchasers may steer a different course in aggregate than their predecessors and avoid becoming accustomed to large cars. Peer group acceptance of smaller cars, already in evidence, may create a different automobile environment as this population group ages and becomes more affluent.

Family Composition

Variation in ownership by family composition appears to be significant whether measured on the basis of family size, the number of adults per household, or the number of licensed drivers per household. With regard to family size, some of the variation can be explained by different income levels, as the following data suggest:

Family Size	Average No. of Vehicles Owned	Family Income Before Taxes
Single person	.6	$ 4,495
Two persons	1.3	9,811
Three persons	1.5	10,227
Four persons	1.7	11,824
Five persons	1.8	12,566
Six or more persons	1.7	12,154
All families	1.3	9,081

Automobile ownership increases as the family size increases until the "six persons or more" category is reached. Family income also increases until this family size category is reached. Consequently, as average income decreases from $12,566 to $12,154, average ownership decreases from 1.8 automobiles to 1.7, despite the fact that family size increases from five to six persons or more.

Tables 2-29 and 2-30 show the average ownership per households by the number of adults per household and the number of licensed drivers per household, respectively. Ownership in households with three or more adults is 275 percent higher than the ownership in one-adult households. Similarly,

TABLE 3-29. HOUSEHOLD AUTOMOBILE OWNERSHIP BY NUMBER OF ADULTS PER HOUSEHOLD, 1969-1970

No. of Adults per Household	Number of Households (thousands)	Number of Automobiles (thousands)	Automobiles per Household
One	13,063	5,918	.453
Two	34,937	41,652	1.192
Three or more	14,500	24,665	1.701
Total, All Households	62,500	72,235	1.156

Note: *Employed same method of estimation as utilized in Census of Housing data. See Text, Section 4.1.5.1.4.*

Source: *Calculated from U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 11, December 1974, p. 19.*

TABLE 2-30. HOUSEHOLD AUTOMOBILE OWNERSHIP BY NUMBER OF LICENSED DRIVERS PER HOUSEHOLD, 1969-1970

Number of Licensed Drivers per Household	Number of Households	Number of Automobiles	Automobiles per Household
One	10,750	9,633	.896
Two	31,250	45,314	1.453
Three	10,250	21,221	2.070
Four or more	4,625	10,685	2.310
Zero	5,450	0	.000
Unknown	187	195	1.045
Total, All Households	62,500	87,148	1.394[a]

[a] *Average ownership for all households is inconsistent with the overall ownership shown in other tables which were derived from the same source. The discrepancy is not reconciled since the purpose is to show the relative ownership by households with different numbers of licensed drivers.*

Note: Imputed zone method of estimation as utilized in Census of Housing data. See text, Section 4.1.3.1.4.

Source: Calculated from U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 11, December 1974, p. 81.

households with four or more licensed drivers maintain automobile ownership greater than 150 percent than that of single-driver households.

2.4 FACTORS WHICH INFLUENCE SCRAPPAGE

A behavioral estimation of scrappage is an important element in the Marketing and Mobility Model structure. Government policies (gas taxes, new car excise taxes based on fuel economy, etc.) can substantially change the relative prices and operating costs of new cars among the market classes. While the primary impact of these changes is on the new car market, important secondary impacts are generated with regard to used cars. For example, a policy which substantially increased the purchase price of large new cars would tend to increase the value of similar used cars. Thus, these large used cars will be maintained longer and driven more than if no policy were implemented. Similarly, if small new vehicles were subsidized, the decreased cost for these new cars will tend to drive down the value of small used cars and increase the scrappage of small used cars. These two effects both result in a lower fleet fuel efficiency for existing cars and tend to mitigate the primary fuel savings generated in the new car market.

The above example assumes that new car prices for a market class are inversely related to used car scrappage in that

market class. An interconnecting link between new car prices and used car scrappage would be used car prices. A recent RAND study (64) found that new car prices strongly influence used car prices (positively) and that the net impact of both new car and used car prices on automobile scrappage is inverse. Also, one would expect maintenance and repair costs of used cars to be positively correlated with automobile scrappage. Another a priori relationship exists between macroeconomic conditions and scrappage: as economic indicators (real disposable income, unemployment, etc.) worsen, there will be a tendency for individuals to maintain their existing cars and not trade up to a new or more expensive used car.

The import of these considerations on the Marketing and Mobility Model is to treat scrappage by class of car as an endogenous variable. This function should be sensitive to new car prices (by class of car), a macroeconomic variable and repair costs (if data are available).

2.5 FACTORS WHICH INFLUENCE AUTOMOBILE TRAVEL DEMAND (VMT)

Travel by Purpose of Trip and Place of Residence

The most important single use of the automobile is for trips related to earning a living. This trip purpose accounts for 16 percent of all automobile-miles. The next largest category of automobile travel by purpose is family business, which represents 31 percent of all trips, but only 19 percent of vehicle-miles, since these trips are usually made over relatively short distances. Social and recreational driving account for 22 percent of all trips but 33 percent of vehicle-miles, reflecting the longer distances traveled by trip-makers of this purpose. Civic, educational, and religious trips account for 9 and 5 percent of all trips and vehicle-miles, respectively. These patterns are detailed in Table 2-11.

Patterns of automobile trip making by purpose do not appear to vary widely by place of residence. Table 2-12 presents data on the percent of all trips and vehicle-miles by trip purpose within each residential category. Two alternative urban/rural classifications are utilized--SMSA/non-SMSA and

TABLE 2-31. - AUTOMOBILE TRAVEL BY TRIP PURPOSE

Trip Purpose	Percent of of Total Automobile Trips	Percent of Total Automobile Vehicle Miles	Average Trip Length (Miles)
Earning a living			
Home-to-work	31.9	33.7	8.4
Related business	4.3	7.9	16.1
Subtotal	36.2	41.6	10.2
Family business			
Shopping	15.2	7.5	4.4
Medical and dental	1.8	1.6	8.4
Other	14.0	10.2	6.5
Subtotal	31.0	19.3	5.6
Civic, educational and religious	9.3	4.9	4.7
Social and recreational			
Visiting friends and relatives	8.9	12.1	12.0
Pleasure driving	1.4	3.1	20.0
Vacations	0.1	2.5	160.0
Other	12.0	15.3	11.4
Subtotal	22.4	33.0	13.1
Other and unknown	1.1	1.2	8.4
Total	100.0	100.0	8.9

Source: U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 10, 1974, p. 13.

TABLE 2-32 · AUTOMOBILE TRAVEL BY TRIP PURPOSE AND PLACE OF RESIDENCE

Trip Purpose	All Areas	SMSAs	Non SMSAs[a]	Incorporated Places	Unincorporated Areas
	Percent of Automobile Trips				
Earning a Living	36.2	36.6	35.3	36.5	35.8
Family Business	31.0	30.7	31.7	30.8	31.5
Civic, Educational, and Religious	9.5	9.2	9.5	8.9	10.0
Social and Recreational	22.4	22.5	22.6	22.8	21.4
Other	1.1	1.2	0.9	1.0	1.3
Total, All Purposes	100.0	100.0	100.0	100.0	100.0
	Percent of Vehicle-Miles of Travel				
Earning a Living	41.6	42.5	39.7	41.5	41.8
Family Business	19.3	18.3	21.4	18.0	21.5
Civic, Educational, and Religious	4.9	4.8	5.1	4.3	6.0
Social and Recreational	33.0	33.4	32.2	35.3	29.0
Other	1.3	1.0	1.6	0.9	1.7
Total, All Purposes	100.0	100.0	100.0	100.0	100.0

[a]*Estimated from data sources; assumed to be equal to the difference between data presented for "All Areas" and "SMSAs."*

Source: *U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 10, 1972.*

incorporated/unincorporated areas. Results show that there is virtually no difference between each area in their respective distributions of trips by purpose

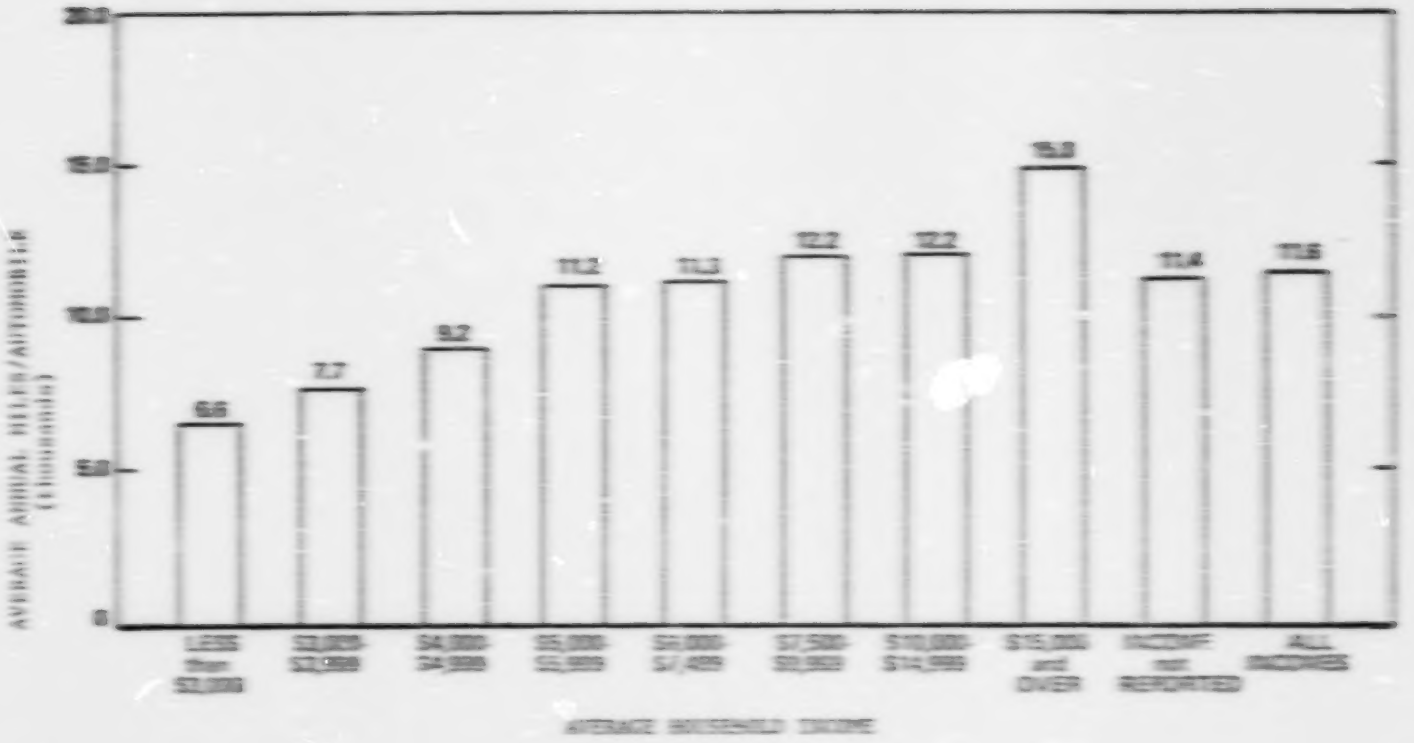
There is some slight variation between places of residence in the distribution of vehicle-miles by trip purpose. This is due to the fact that while the number of trips is very similar, the average trip length differs somewhat with the degree of urbanisation. For a given purpose, the ratio of the percent of automobile trips to the percent of vehicle-miles provides an inverse indication of the relative trip length by place of residence. Areas where the average trip length is longer will have a lower value for this ratio. It appears that the metropolitan areas have higher relative trip lengths for "earning a living" and "social and recreational" trips, while the non-metropolitan areas have higher relative trip lengths for automobile trips relating to "civic, educational and religious" and "family business." Incorporated places represent a relatively higher trip length for social and recreational driving, while the unincorporated areas reflect higher average trip length for the remaining three purpose categories.

The variations observed by place of residence on the distribution of trips or vehicle miles by trip purpose is not sufficient to justify a geographical disaggregation in the VMT estimates to be used in the Marketing and Mobility Model.

Travel by Income and Purpose of Trip

Automobile travel maintains a positive relationship with income. As illustrated in Figure 2-4, the average annual miles driven per automobile increases steadily as one goes from low-income to high-income groups. The average VMT per automobile for households with incomes of $15,000 and over is more than twice the average for households with income below $3,000 (1969 to 1970 dollars).

Table 2-11 shows the relative patterns of automobile travel by trip purpose for four selected income groups. Two measures of travel are utilized--the number of automobile trips and the amount of vehicle-miles traveled. On the trip basis, the patterns of the three income groups above $4,000 are virtually the same but differ from that of the below $4,000 category. The low-income group represents fewer trips made for "earning a living" than the other income classes, but relatively more trips for "family business" and "social and recreational" travel. The variation in travel



Source: U.S. Department of Transportation, National Highway Administration, Nationwide Personal Transportation Study, Report Number 3, April 1972.

FIGURE 2-4. AVERAGE ANNUAL MILES PER AUTOMOBILE BY ANNUAL HOUSEHOLD INCOME

TABLE 2-13-AUTOMOBILE TRAVEL BY TRIP PURPOSE AND HOUSEHOLD INCOME

Trip Purpose	Annual Household Income			
	Under $4000	$4000-$9999	$10000-$14999	$15000 and over
	Percent of Automobile Trips			
Earning a Living	29.0	37.0	37.9	38.2
Family Business	34.9	30.8	30.2	30.4
Education, Civic and Religious	7.7	9.6	10.5	10.2
Social and Recreational	27.8	22.7	20.7	21.6
Other	2.6	0.9	1.2	1.6
Total, All Purposes	100.0	100.0	100.0	100.0
	Percent of Vehicle-Miles Travelled			
Earning a Living	31.0	39.6	44.0	47.4
Family Business	37.1	33.0	28.0	27.2
Education, Civic and Religious	4.4	4.9	5.3	5.5
Social and Recreational	25.7	34.2	21.5	20.6
Other	1.8	1.3	1.2	1.2
Total, All Purposes	100.0	100.0	100.0	100.0

Source: U.S. Department of Transportation, Federal Highway Administration, Automobile Personal Transportation Data, Report Number 7, December 1972.

patterns among income groups is greater on the basis of VMT. As household income levels rise, increasing portions of total automobile travel are accounted for by "earning a living" and decreasing amounts represented by "family business" and "social and recreational."

In view of the strong relationship between income and automobile usage, income should be an important element in the Marketing and Mobility Model VMT estimator. However, in the context of a time series analysis of VMT, a disaggregate forecast of travel by purpose is not feasible. Trip purpose data are only partially available at the national level from census and the Nationwide Personal Transportation Study. At the local level, most urban areas have independent trip purpose data from home-interview surveys. At either level, these cross sectional surveys are generally available for only one year (at the most two).

Travel by Age of Driver

Average annual miles driven per driver by age of driver are shown in Table 2-14. Drivers 30 to 34 years maintain the highest average, nearly 20 percent higher than the total

TABLE 2-14 AUTOMOBILE TRAVEL BY AGE OF DRIVER, 1969-1970

Age Group (years)	Average Annual Miles Driven per Driver	Percent of Total VMT	Percent of Total Licensed Drivers
16 - 19	4,633	4.6	9.0
20 - 24	6,260	12.6	13.1
25 - 29	9,814	13.0	11.5
30 - 34	10,274	11.3	9.3
35 - 39	9,878	10.5	8.1
40 - 44	9,855	11.1	9.7
45 - 49	9,875	11.1	9.7
50 - 54	9,447	8.8	8.2
55 - 59	9,000	7.1	6.8
60 - 64	8,112	5.0	5.4
65 - 69	5,850	2.4	3.7
70 & over	4,044	2.5	4.7
All ages	8,685	100.0	100.0

Source: *U.S. Department of Transportation, Federal Highway Administration, Nationwide Personal Transportation Study, Report No. 8, April 1972.*

average for all drivers. Drivers in the range of 25 to 59 years all are above the overall average. Very young drivers, 16 to 19 years, and very old drivers, 70 or more, are at the bottom of the scale and both represent only 53 percent of the overall average. The range of variation from drivers 30 to 34 to drivers 16 to 19 is over 120 percent.

Table 2-35 shows the trend in relative number of drivers in each age group for 1965, 1969, and 1973. Over the period 1965-1973, positive relative changes in the number of drivers have occurred at the beginning and end of the age spectrum--ages 16-29 and 60 and over. The age groups 30-54 all showed negative changes. Assuming the relative pattern of VMT per driver in each age group remains constant, a continuance of this trend--a shift from high average-VMT-drivers to lower average -VMT-driver--should result in a lower overall average in the future.

As with trip purpose data, travel characteristics by age are not available for several different time periods. Consequently, the temporal stability of the relationships observed in Table 2-34 and 2-35 is uncertain. Inclusion of variations of this variable over time would not be feasible.

TABLE 2-35 - LICENSED DRIVERS BY AGE GROUP
1965, 1969, and 1973
(percent of total licensed drivers)

Age Group (years)	1965	1969	1973	Relative Change 1965 - 1973 (percentage points)
Under 16	0.1	0.1	0.1	0.0
16 - 19	8.7	8.6	8.9	+0.2
20 - 24	11.8	12.7	13.3	+1.5
25 - 29	10.5	11.1	12.2	+1.7
30 - 34	10.2	9.8	10.1	-0.1
35 - 39	10.8	9.8	8.7	-2.1
40 - 44	10.7	9.9	8.6	-2.1
45 - 49	9.5	9.1	8.6	-0.9
50 - 54	8.3	8.2	8.1	-0.2
55 - 59	6.8	7.0	6.8	0.0
60 - 64	5.1	5.4	5.6	+0.5
65 - 69	3.6	3.8	4.1	+0.5
70 & over	3.9	4.2	4.9	+1.0
Total, All ages	100.0	100.0	100.0	

Source: U.S. Department of Transportation, Federal Highway Administration, Drivers Licenses.

Economic Factors

The major economic factor affecting automobile travel is the fuel cost per mile traveled. This factor is made up of two components --the price of gasoline ($ per gallon) and the fuel economy (mile per gallon). In the short run, people are more sensitive to gas price changes since they usually hold on to their car, and thus maintain basically the same fuel economy for several years. In the long run, people can adjust to the rising total fuel cost by purchasing a more fuel efficient automobile.

Gasoline Price Trend

Data on the average service station price (including taxes) of regular-grade gasoline at 55 representative cities is available historically from Platt's Oil Price Handbook and Oilmanac. This price series is shown in Table 2-36. Over the period 1950 to 1973 (pre-embargo), the price of gas increased at an average annual growth rate of 1.6 percent. However, in 1974, reflecting the pressures caused by the oil embargo, the price of gas increased by 35 percent over the previous year! While the nominal price has been steadily increasing, the real price of gas (nominal series deflated by the CPI, all items) has been generally declining. Even the real price in 1974, which jumped 22 percent from the previous year, was lower than that recorded in 1950. The real fuel cost per mile for the entire automobile fleet (real

gas price divided by the fleet fuel economy, discussed below), has also exhibited a declining trend since the mid-1950s, except for the last two years which show a reversal of the trend. These data series are also shown in Table 2-36.

Fuel Economy Trends: Automobile Fleet Versus New Cars

The trend in miles per gallon for the automobile fleet and for new cars is shown in Table I-17 and Figure 2-5. Both measures of fuel economy have shown general declines since the early 1950s. However, new cars have experienced a relatively greater decrease in fuel economy--14.6 percent from 1957 through 1973--compared to the average for the fleet--8.6 percent over the same period. The fleet fuel economy has not declined as much as the new car mpg, since the increment to the total fleet represented by the annual new car sales is relatively small. The 1973 model year cars accounted for only 8.9 percent of the total cars in use as of July 1, 1973 (3).

For purposes of forecasting, fuel economy data (by market class) for future years will be provided to the Marketing and Mobility Model by the Automotive Design Panel.

TABLE 3-16 GASOLINE PRICES AND FUEL COST PER MILE 1950 - 1974

Year	Nominal Gas Price ($/gal)	Real Gas Price 1967 Dollars ($/gal)	Real Fuel Cost per Mile[a] ($)	Real Fuel Cost per Mile Index[b] (1967=1.00)
1950	.2076	.3712	.0248	1.042
1951	.2245	.3490	.0253	.970
1952	.2256	.3467	.0250	.992
1953	.2860	.3582	.0244	1.025
1954	.2904	.3607	.0248	1.042
1955	.2907	.3625	.0250	1.050
1956	.2905	.3677	.0256	1.076
1957	.3096	.3678	.0258	1.071
1958	.3058	.3508	.0245	1.020
1959	.3040	.3493	.0244	1.025
1960	.3115	.3510	.0246	1.034
1961	.3076	.3453	.0250	1.004
1962	.3064	.3384	.0245	.987
1963	.3042	.3317	.0233	.970
1964	.3035	.3207	.0220	.962
1965	.3115	.3206	.0224	.983
1966	.3208	.3300	.0236	.992
1967	.3516	.3516	.0248	1.000
1968	.3571	.3435	.0235	.987
1969	.3480	.3160	.0233	.970
1970	.3569	.3060	.0226	.950
1971	.3643	.3003	.0224	.929
1972	.3613	.2883	.0214	.899
1973	.3882	.2917	.0225	.957
1974	.5241	.3548	.0272	1.130

[a] *Based on fleet fuel economy.*

[b] *Assumed the 1974 fleet fuel economy.*

Sources: Platt's Oil Price Handbook and Oilmanac for nominal price series; U.S. Department of Labor, Bureau of Labor Statistics, for Consumer Price Index; and Table 40 for fleet fuel economy.

TABLE 2-37 AVERAGE FUEL ECONOMY FOR THE AUTOMOBILE FLEET AND NEW CARS

(miles per gallon)

Year	Average Fleet Fuel Economy (calendar year basis)	New Car Fuel Economy (model year basis)
1950	14.95	.
1951	14.99	.
1952	14.67	.
1953	14.70	.
1954	14.58	.
1955	14.53	.
1956	14.36	.
1957	14.40	13.67
1958	14.30	14.07
1959	14.30	13.85
1960	14.26	13.36
1961	14.38	13.55
1962	14.37	13.96
1963	14.26	12.62
1964	14.25	13.49
1965	14.07	12.98
1966	14.00	12.95
1967	13.93	12.86
1968	13.79	12.44
1969	13.63	12.21
1970	13.57	12.51
1971	13.57	12.21
1972	13.49	12.03
1973	13.10	11.67

Note: Motorcycle travel is included in average fleet fuel economy for 1951-64.

Sources: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, and U.S. Environmental Protection Agency, A Report on Automobile Fuel Economy, October 1973.

miles per gallon

Travel on Urban and Rural Roads

Most automobile travel takes place on urban facilities and the urban share of highway traffic has been steadily increasing since the mid-fifties. In 1973, automobile travel totaled 1017 billion vehicle-miles, of which 57 percent took place on urban streets and 43 percent on rural roads. The urban share has gradually increased from a low of 45 percent in 1955, reflecting the trend of increasing urbanisation in this country. Historical data on urban and rural automobile travel since 1950 are presented in Table 2-38. The relative growth of travel in both areas is shown by the following annual growth rates:

Time Period	Total	Urban	Rural
1950-1973	4.6%	5.2%	1.9%
1950-1960	4.9%	4.6%	5.1%
1960-1973	4.3%	5.6%	2.8%

The increasing volume of traffic on urban streets is accentuated by comparing its growth since 1960, where its annual rate is twice that of rural roads. This trend is further illustrated by the graph in Figure 2-6.

Projections of these shares are not expected to follow the historical trend for two reasons: construction of the urban segments of the interstate highway system appears near completion

TABLE 2-38 : AUTOMOBILE TRAVEL
URBAN VS. RURAL ROADS, 1950-1975

Year	Total Travel[a]	Travel on Urban Streets[a]	Percent of Total	Travel on Rural Roads[a]	Percent of Total
1950	363.6	182.5	50.2	181.1	49.8
1951	392.1	186.8	50.3	205.3	48.7
1952	410.2	188.1	50.2	222.1	48.8
1953	435.4	197.8	47.6	237.6	52.4
1954	453.2	208.9	45.9	244.3	54.1
1955	492.6	233.6	45.4	259.0	54.6
1956	514.8	245.2	46.1	269.6	53.9
1957	530.4	254.4	47.4	275.0	52.6
1958	544.0	263.6	47.6	281.3	52.4
1959	573.0	277.8	48.1	295.2	51.9
1960	588.1	284.8	48.4	303.3	51.6
1961	604.6	292.1	48.5	312.5	51.5
1962	629.1	316.8	48.4	312.3	51.6
1963	645.4	325.0	48.3	320.4	51.7
1964	677.6	340.6	50.3	337.0	49.7
1965	706.4	375.8	53.2	330.6	46.8
1966	744.8	397.0	53.3	347.8	46.7
1967	766.5	410.8	53.6	355.7	46.4
1968	805.7	434.3	53.9	371.4	46.1
1969	849.6	461.3	54.3	388.3	45.7
1970	890.8	489.0	54.9	401.8	45.1
1971	959.1	536.5	55.6	422.6	45.0
1972	986.4	558.3	56.6	428.1	43.4
1975	1016.9	580.7	57.1	436.2	42.9

[a]*Billions of vehicle-miles.*

Note: Travel for 1967-81 includes metropolis. For 1950-75, total travel includes metropolis while urban/rural distribution is based on percentages calculated from vehicle-miles which includes metropolis.

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics.

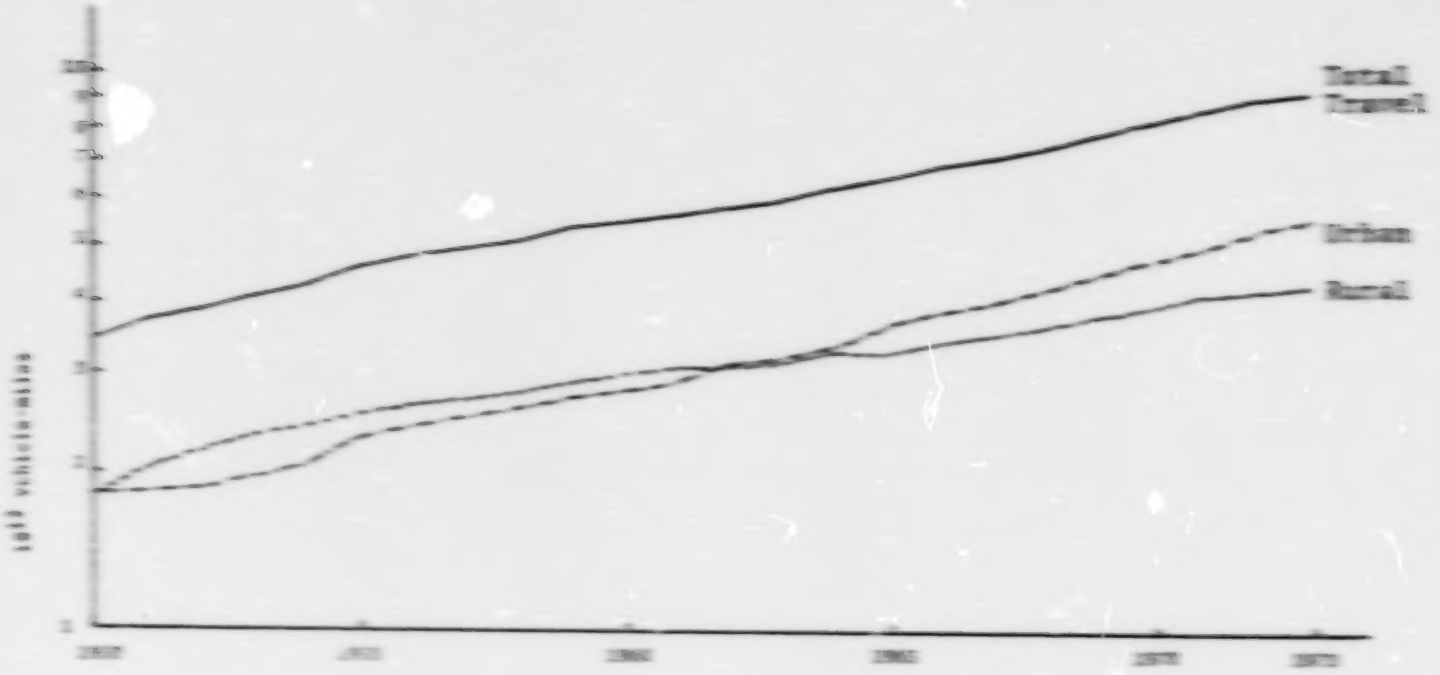


FIGURE 2-6. -AUTOMOBILE TRAVEL: URBAN VS. RURAL ROADS, 1950 - 1973

and the growth in population shifts to urban areas appears to be slowing down. Historical and forecasted shares of SMSA and non-SMSA population, a proxy for urban/rural population changes, are shown below (56):

Year	Percentage Shares of Total Population	
	SMSA	Non-SMSA
1950	64.4	35.6
1970	71.0	29.0
1980	72.1	27.9
1990	73.4	26.6
2000	74.4	25.6

Projections of the urban share of VMT were derived by first calculating the ratio of the percentage change in the urban VMT share from 1950 to 1970, to the percentage change in the urban population share for the same period; this ratio equaled .99274. The projected growth rate of the urban VMT share was estimated by applying this ratio to the forecasted change in the urban population share over the period 1980 to 2000. The average annual growth thus obtained was 0.125 percent. Assuming the same growth from 1973 to 1980 as that for 1980 to 2000, we applied this growth rate to the 1973 share (the last year for which actual urban and rural VMT is recorded) and obtained an urban share of VMT of 58.9 percent in the year 2000, compared to the 1973

share of 57.1 percent. Because of the very small change taking place over this time period, interpolation for the intervening years was made by utilising equal annual increments throughout the period. The forecast of both urban and rural VMT shares is shown in Table 2-39.

Congestion

Congestion is an aspect of automobile travel that is extremely difficult to quantify. Lack of uniformity among areas (and even within a single area) make attempts at constructing a nationwide congestion index a futile exercise. Conceptually, congestion is a measure of the relationship between the actual speed one travels on a given road to the speed that the road would permit in the absence of other traffic. Trying to estimate a historical trend for congestion raises the problem of a changing "product"--namely, the roads today are quite different from the roads of twenty years ago. Facilities have become wider and have faster design speeds so that any historical comparison is subject to skepticism. Nevertheless, a trend which is possibly related to congestion is the vehicle-miles traveled per mile of facility. The trend in this index for both urban and rural roads is shown in Table 2-40. With the ratio of VMT

TABLE 2-19 PROJECTIONS OF VEHICLE MILES TRAVELLED ON URBAN AND RURAL ROADS, 1975-2000
(percent of total VMT)

Year	Urban Roads	Rural Roads
1975	57.2	42.8
1976	57.3	42.7
1977	57.4	42.6
1978	57.4	42.6
1979	57.5	42.5
1980	57.6	42.4
1981	57.6	42.4
1982	57.7	42.3
1983	57.8	42.2
1984	57.8	42.2
1985	57.9	42.1
1986	58.0	42.0
1987	58.0	42.0
1988	58.1	41.9
1989	58.2	41.8
1990	58.2	41.8
1991	58.3	41.7
1992	58.4	41.6
1993	58.4	41.6
1994	58.5	41.5
1995	58.6	41.4
1996	58.6	41.4
1997	58.7	41.3
1998	58.8	41.2
1999	58.8	41.2
2000	58.9	41.1

TABLE 2-42 -TREND IN VEHICLE-MILES TRAVELLED PER MILE OF FACILITY: URBAN VS. RURAL ROADS

Year	VMT on Urban Roads (Millions)	Total Surfaced Municipal Mileage	Ratio of VMT to Mileage	VMT on Rural Roads (Millions)	Total Surfaced Rural Mileage	Ratio of VMT to Mileage
1950	219,148	260,092	.8391	139,994	1,678,619	.1430
1955	275,185	330,325	.8329	190,541	1,942,413	.1782
1960	331,585	391,582	.8470	387,260	2,185,466	.1748
1965	449,040	473,938	.9475	438,771	2,382,119	.1808
1970	577,373	535,391	1.0784	543,351	2,411,872	.2253
1972	678 115	588,147	1.1530	590,227	2,433,395	.2426
Average Annual Growth Rate, 1950-1972	5.31	3.81	1.54	6.78	1.71	2.58

Note: VMT is for total motor vehicles.

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics.

to mileage of facility serving as a proxy for congestion, it would appear that congestion has increased in both urban and rural areas. However, the rural areas seem to represent a higher relative growth in congestion. This finding is further substantiated by a study on changes in mobility which concludes that many cities show improvement in the area of congestion and that "we should be ready to increase the priority of the transportation needs of outlying areas." (34)

Public Transportation

Intuitively, the future supply of public transportation would seem to be an important variable to account for when forecasting total automobile travel. In particular, there has been considerable support for substantially increasing the quality of urban public transportation. Compared to future changes in inter-urban public transportation, urban transit supply is a much more uncertain variable whose future course is largely dependent on the willingness of local, State, and Federal agencies and legislative bodies to provide subsidies to maintain or improve service in the face of rapidly escalating costs. Consequently, there is a substantial variance

inherent in the expected levels of urban transit supply. How do these uncertainties impact the estimation of automobile travel in the context of the Marketing and Mobility Model?

To begin with, only one trip in twenty-five is made by some form of public transportation in the United States today (22). Therefore, if travel on public modes increased by 50 percent and if all of this new travel were diverted from previous automobile travel, this would represent only a two percent decrease in automobile travel. However, available evidence suggests that only a minority of new transit trips would result from automobile diversions. For example, an extension of the Chicago rail transit down the Dan Ryan Expressway (9.5 miles through the Chicago Loop) resulted in insignificant automobile diversions. A Chicago Transit Authority survey indicated that only 8 percent of the passengers were formerly automobile drivers while 80 percent were formerly users of some other form of public transportation (27). Similar results were observed when the Boston MBTA extended rapid transit to the Quincy area south of Boston. Measurements showed no difference in traffic on the roads parallel to the extension.(27)

Statistical studies have estimated inelastic transit demand with respect to fare and line haul travel time, although the transit demand elasticity with respect to wait time is generally estimated to be somewhat higher (10, 17, 25, 31-33, 37-42, 53, 54, 55, 63). Since only a minority of new future transit riders are likely to be diverted from the "automobile-driver" mode and since total transit demand is small relative to total automobile travel, the cross elasticity of transit demand with respect to transit service characteristics is very low.

In the context of the Task Force objectives and the Marketing and Mobility Model, the supply of public transit services is not a policy variable. Future forecasts of public transit supply would be impossible to derive except by assuming particular local, State, and Federal policies with regard to the funding of public transit. Because of the factors outlined above, even large variations in these assumptions would result in small impacts on aggregate vehicle miles traveled forecasts. Further, the impacts of public transit supply would have to be analyzed in the contest of a regional analysis for all urban areas (individually) or aggregations of similar urban areas (see reference 47). The potential impact of such an analysis

does not justify the effort unless one were specifically interested in analysing public transit policy. Consequently, the Marketing and Mobility Model will not consider potential changes in public transit supply. However, that should not be interpreted to indicate any attitude of the Marketing and Mobility Panel towards public transit per se.

2.6 DETERMINATION OF MARKET CLASSES

The Task Force has adopted a market classification scheme which identifies all passenger cars as being small, mid-size, or large. The criterion for classifying future automotive designs into these three categories is a "roominess" index which is obtained by summing seven measurements of each make and model, namely:

- seat height, front
- head room, front
- head room, rear
- leg room, front
- leg room, rear
- shoulder room, front
- shoulder room, rear

These data are not available for automobiles more than three years old and therefore could not be used to define market shares with respect to historic data. Before discussing how market shares were determined, it is useful to review market classifications used in other studies.

Transportation Systems Center (59). In the past TSC has utilized a three-group scheme that corresponds roughly to the Automotive News breakdown: small, composed of subcompacts and imports; medium, which includes compacts, intermediates, and small luxury cars; and large, which contains the standards. The classes are defined on the basis of inertia weight. Small cars are those below 3,200 pounds, medium cars are those between 3,200 and 4,500 pounds, while cars over 4,600 pounds are classified as large. Average price and fuel economy per class are not available, but the latter can be derived on a sales-weighted basis from data on sales by model year and inertia weight class and data on miles per gallon by model year and inertia weight class. The time period for which these data are available is 1958 to 1973. Historical market share data are shown in Table 3-41.

Federal Energy Administration. The Office of Energy Systems has developed a classification scheme that contains five groups--domestic makes broken down into three categories and imports into two. Cars are grouped together largely on the basis on vehicle weight and horsepower. The classification process is as follows: for each domestic make

TABLE 3-41 -NEW CAR MARKET SHARES-
TRANSPORTATION SYSTEMS CENTER: 1957-1973
(percent of total sales)

Date	Small	Medium	Large
1957	7.4	79.0	13.6
1958	7.4	79.0	13.6
1959	13.0	70.7	16.3
1960	23.0	60.0	17.0
1961	31.8	58.9	13.3
1962	21.6	63.7	14.7
1963	20.0	65.0	15.1
1964	19.5	67.5	13.0
1965	14.8	70.1	15.1
1966	14.5	69.0	15.6
1967	14.1	69.3	16.1
1968	11.0	73.4	15.6
1969	14.1	61.0	24.9
1970	20.7	56.4	22.9
1971	23.0	49.8	27.2
1972	22.0	49.5	28.4
1973	24.5	41.6	33.8

Source: U.S. Department of Transportation, Transportation Systems Center, Preliminary Base Period Fleet Projections for Fuel Economy Improvement Program, Motor Vehicle Goals Beyond 1980, draft working paper.

and model of 1972 automobiles, price (P) is regressed on weight (W) and horsepower (HP) according to the form

$$\log P = a + b_1 W + b_2 HP$$

This index is used to classify other model years. Two intermediate cutoff points are determined which delineate the index into three groups or market classes. These coefficients are assumed to be constant for each year over the period 1956 to 1973. Each vehicle's classification is therefore determined by substituting its respective weight and horsepower in the above equation and observing the value of the log P index that it assumes. The two import classes are determined in similar fashion. Vehicle prices, weights, and horsepower are those presented in Automotive News. Class features are an arithmetic average price and a sales weighted mpg based on EPA data of fuel economy by weight class and model year.

Aerospace Corporation (1). This study in 1973 categorizes new car sales (domestic and imports combined) into five market classes--standard, intermediate, compact, subcompact, and

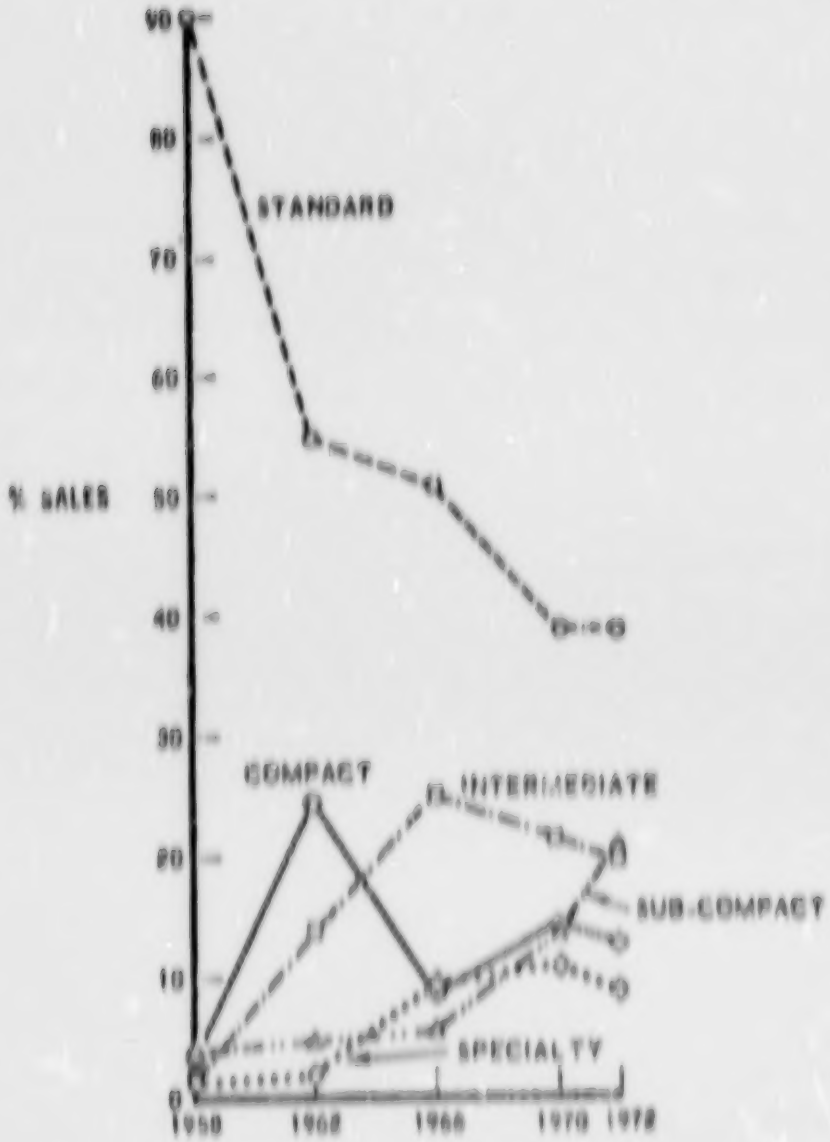


FIGURE 2-7.- PASSENGER CAR REGISTRATIONS BY MARKET CLASS-THE AEROSPACE CORPORATION

Source: The Aerospace Corporation, *Passenger Car Weight Trend Analysis*, July 10, 1978.

specialty. These groups are known as "industry standard market class breakdowns." Four of these classes are defined by wheelbase specifications, while cars of the fifth class, specialty sizes, encompass the entire wheelbase range. New car sales by market class are presented for five years: 1958, 1962, 1966, 1970, and 1972. The percent of total sales by each class is shown in Figure 2-7. A sales-weighted curb weight and inertia weight is calculated for each class and year. Other sales-weighted averages for each of five classes of domestic makes and two classes of imports (compact and subcompact) are wheelbase dimension, overall width, overall length, total overhang (overall length-wheelbase), engine displacement and compression ratio.

Chase Econometric Associates, Inc. (12). The Chase study also breaks down market classes into five groups. It accepts with only minor alterations the Aerospace definitions of subcompact, compact, and intermediate. The Aerospace "standard" is divided into a new standard and a luxury class, the division made on the basis of price. Finally, cars of the Aerospace "specialty" class are assigned to all five classes mainly on the basis of price also. Consequently, market classes are

defined on the basis of wheelbase size and price (suggested retail price from Automotive News). Chase interpolated the Aerospace data to present new car market shares annually from 1958 to 1972, shown in Table 2-42. Sales weighted averages on relative price, relative inertia weight, and relative mpg by market class are also presented for this time period.

Energy and Environmental Analysis, Inc. (19). EEA is currently using the Chase classifications, but foresees the addition of a new class of luxury small cars and some other minor adjustments.

Chamberlain (11). This cross-sectional study uses the five group classification of R. L. Polk and Company which defines classes solely on the basis of price (see Automotive News, Almanac issues). The classes are compact and subcompact, intermediate, full size, high-price full size specialty, and luxury.

Motor Vehicle Manufacturers Association (44). MVMA compiles shares of new car deliveries by domestic makes--seven classes--

TABLE 2-42 -RELATIVE SALES SHARES BY SIZE-CLASS-
CHASE ECONOMETRIC ASSOCIATES, INC.: 1958-1972

Year	Subcompact	Compact	Intermediate	Standard	Luxury
1958	.06	.24	.01	.66	.23
1959	.09	.06	.04	.67	.15
1960	.08	.15	.22	.45	.10
1961	.07	.17	.17	.48	.10
1962	.07	.16	.20	.47	.10
1963	.05	.15	.19	.49	.10
1964	.05	.17	.22	.45	.11
1965	.06	.16	.22	.43	.13
1966	.08	.15	.25	.38	.16
1967	.08	.15	.25	.36	.16
1968	.09	.14	.27	.34	.16
1969	.10	.16	.25	.31	.18
1970	.15	.19	.25	.27	.16
1971	.20	.15	.21	.26	.18
1972	.20	.15	.23	.25	.18

Source: Chase Econometric Associates, Inc., The Effect of Tax and Regulatory Alternatives on Car Sales and Gasoline Consumption, submitted to theCouncil on Environmental Quality, May 1974.

and imports. These data are shown in Table 2-41 for 1969 through 1974. Classification is determined by judgment based on wheelbase, price and weight.

Ward's (62). New car registrations are classified by this service into eight groups--seven domestic categories plus imports. Judgment based on wheelbase, price, and weight are the means of classification. Data on market shares for 1966 to 1973 are shown in Table 2-44.

Automotive News (3). Eight market categories are employed in this classification--three small domestic classes, one intermediate, and three standard classes, plus imports. Shares are based on retail sales and tabulation only began in 1973. Data for 1973 and 1974 are shown in Table 2-45. Once again, classes are defined on the basis of judgment concerning the wheelbase, price, and weight of each model.

A summary of the alternative automobile classifications and how each is defined is presented in Table 2-46.

TABLE 3-43.-U.S. NEW CAR DELIVERIES BY CLASSES-
MOTOR VEHICLE MANUFACTURERS ASSOCIATION: 1968-1974
(percent of total U.S. market)

Classes	1968	1969	1970	1971	1972	1973	1974
Domestic							
Sub-Compact	0.1	*	1.8	7.4	8.2	9.4	8.9
Compact	6.5	9.4	13.4	11.4	12.3	14.0	17.4
Sport	8.5	7.0	6.5	4.3	2.8	3.9	6.8
Passenger Van	0.5	0.6	0.6	0.6	0.7	0.8	1.0
Intermediate	25.6	25.0	22.2	19.6	21.2	21.6	22.7
Regular	41.0	40.1	34.1	33.4	31.8	29.3	21.9
High	7.5	8.3	6.2	8.1	8.2	5.6	5.3
Imports	10.3	11.6	15.2	15.2	14.8	15.4	15.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Less than 0.1%.

Source: Compiled by Motor Vehicle Manufacturers Association of the U.S., Inc., February 24, 1975.

TABLE 3-44 -/ U.S. NEW CAR REGISTRATIONS BY GENERAL MARKET CLASSES-
WARD'S AUTOMOTIVE YEARBOOK: 1966-1973

(percent of total market)

Year	High Price	Medium Price	Regular Size	Inter-mediate Size	Compact Size	Sub-compact Size	Specialty/ Sports Type	Foreign Cars
1966	2.6	17.9	30.4	23.6	8.4	-	9.4	7.3
1967	2.9	17.8	29.6	22.8	6.7	-	12.8	9.3
1968	2.6	17.0	27.0	24.0	7.1	-	11.7	10.5
1969	2.9	16.6	25.9	22.2	9.5	-	11.1	11.2
1970	2.5	15.7	22.5	21.0	10.5	1.6	10.3	14.7
1971	2.7	15.2	20.8	18.1	12.1	7.4	8.6	15.1
1972	2.6	14.8	19.2	18.5	13.1	8.2	8.1	14.6
1973	2.6	12.8	15.9	17.1	14.7	9.4	10.3	15.1

Source: Ward's Automotive Yearbook.

TABLE 2-45 -NEW CAR SALES CLASS-SIZE BREAKDOWN-
AUTOMOTIVE NEWS: 1975-1974

(percent of total market)

Class	1975	1974
Subcompact	9.4	8.9
Compact	16.8	20.3
Luxury Small	1.4	4.1
Intermediate	23.4	24.4
Low Standard	15.4	12.3
High Standard	14.4	10.0
Luxury Standard	3.7	3.6
Imports	15.4	16.0
Total[a]	100.0	100.0

[a]*May not add to total due to independent rounding.*

Source: *Calculated from data in* Automotive News, *1976 Almanac Issue.*

TABLE 2-46 -SUMMARY OF ALTERNATIVE AUTOMOBILE MARKET CLASSIFICATIONS

Source	Market Classes	How Defined	Comments
[illegible]	(3) Small, Medium and Large	Weight	Annual percentage shares, 1957-1973
[illegible]	(3) Three Domestic and Two Imports	Weight and Horsepower	Classification not available yet
Aerospace	(7) Standard, Intermediate, Compact, Subcompact and Specialty	Wheelbase	Data available for 1958, 1960, 1966, 1970, and 1972
Chase	(5) Luxury, Standard, Intermediate, Compact and Subcompact	Wheelbase and Price	Interpolated Aerospace data to provide annual series, 1958-72
Chamberlain	(7) Compact and Subcompact, Intermediate, Full Size, High Price Full Size Specialty, and Luxury	Price - Full Price Classes	
[illegible]	(5) Domestic - Subcompact, Compact, Sport, Passenger Van, Intermediate, Regular, High Price, and Imports	Judgment based on wheelbase, price and weight	Annual shares, 1959-70
Ward's	(7) Domestic - Subcompact, Compact, Intermediate, Specialty[illegible]-to Type, Regular Size, Medium Pric[illegible]igh Price and Imports	Judgment based on wheelbase, price, and weight	Annual shares, 1965-73
Automotive News	(5) Domestic - Subcompact, Compact, Luxury Sport, Intermediate, Low Standard, High Standard, Luxury Standard, and Imports	Judgment based on wheelbase, price, and weight	Annual shares, 1973-74. Delineations of market classes keep changing

Except for the classification system applied by Transportation Systems Center, all of the classification methods use more than three market classes. The TSC system based on inertia weight was a reasonable candidate for the Marketing and Mobility Model classification. However, it was hoped that a set of categories could be devised which would more closely correspond to the roominess index used by the Automotive Design Panel. Of the data bases available to the Marketing and Mobility Panel, the one with the most detailed automobile characteristic variables was based on data published in Automotive News Almanac. While the roominess index variable was not available from this source, two related measures--the interior volume and weight--were. Since model by model observations of the roominess index, interior volume and weight, were available, a regression analysis was performed to determine which variable (or combination) should be used to define classes and what values of the variable should be used to separate small cars from mid-size and mid-size from large. Volume turned out to be an unsatisfactory variable in this regard since it generated an unstable class structure with the proportion of small, mid-size, and large cars varying considerably from year to year. It was clear that share demand has not been that volatile and that styling changes were responsible for this outcome. Inertia weight proved to be a

much more satisfactory variable in reproducing the roominess index classification while maintaining a stable data base with which to develop a market shares model. The break points were:

Class	Weight Index
small	under 3050 pounds
mid-size	3050 - 3500 pounds
large	more than 3500 pounds

Only six misclassifications were produced out of 52 models when the above categorization was compared to that based on the roominess index.

It is important to note that the use of weight to classify historic automobile data into market classes does not imply that future cars are also so classified. The Automotive Design Panel will produce automobile design scenarios that involve lighter structures for given market classes. It is assumed that consumers will still perceive these lighter cars to be in the same market class so long as interior dimensions are maintained.

The vehicle classification system applied here was not selected primarily from the point of view of marketing or estimating market share demand. Its choice was largely to simplify the automotive design parameters and keep the associated analysis within manageable proportions. Nonethe'ess, the three classification system does obscure differences of cars within classes. There is evidence that the reason for the proliferation of sizes and models is other than the desire to have broad product lines. Within each of the three size categories are cars that can be classified as "economy," "mid-priced," or luxury" and some that can be classed as "sporty." The desired characteristics of these cars differ. The cost of operation is apt to be more important for the "economy" car, styling is likely to be important in "luxury" purchases, and handling andperformance are important for "sporty" car purchases. To lump these groups together necessarily obscures some aspects of consumer preference.

2.7 FUNCTIONAL FORMS AND INTERRELATIONSHIP BETWEEN EQUATIONS

Introduction

The foregoing analysis has identified certain exogenous variables which, in addition to those required by the Task Force (Table 2-4), should be included in a model to forecast automobile and travel demand. These variables are listed in Table 2-47. They meet two requirements: (1) there is a clear relationship between each exogenous variable and the variables which the model must produce endogenously as a behavioral estimate; (2) the exogenous variables can be forecast more reliably than the primary endogenous variables (automobile demand and travel demand). The second criterion is particularly important because of the long time horizon which the forecasts are intended to span.

The Task Force structure has predetermined the basic outlines of the Marketing and Mobility Model Structure. This was schematically identified in Figure 2-1 and this figure is repeated. The box labeled Marketing and Mobility Model contains all of the behavioral relationships necessary to

TABLE 2-47

ESSENTIAL EXOGENOUS
VARIABLES TO FORECAST
AUTO AND TRAVEL DEMAND

AUTOMOBILE DEMAND

- Household Income
- Automobile Price Characteristics
- Automobile Fuel Economy Characteristics
- Scrappage (Endogenous)
- Fuel Price

MARKET SHARES DEMAND

- Relative Automobile Price Characteristics by Market Class
- Relative Automobile Fuel Economy Characteristics by Market Class
- Fuel Price

SCRAPPAGE

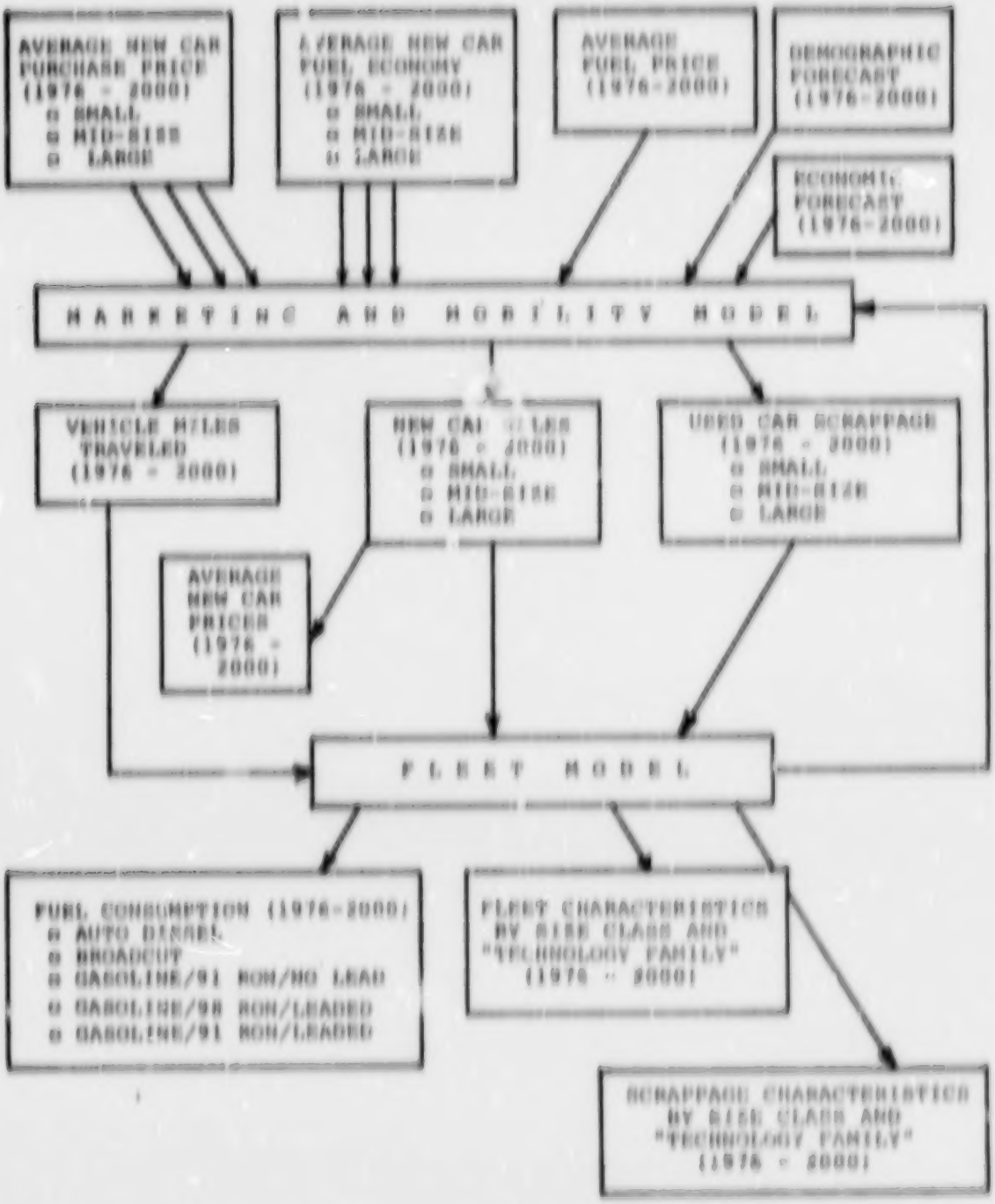
- New Car Prices by Market Class
- Economic Variable

VEHICLE MILES TRAVELED

- Automobiles Available
- Fleet Fuel Economy
- Fuel Price

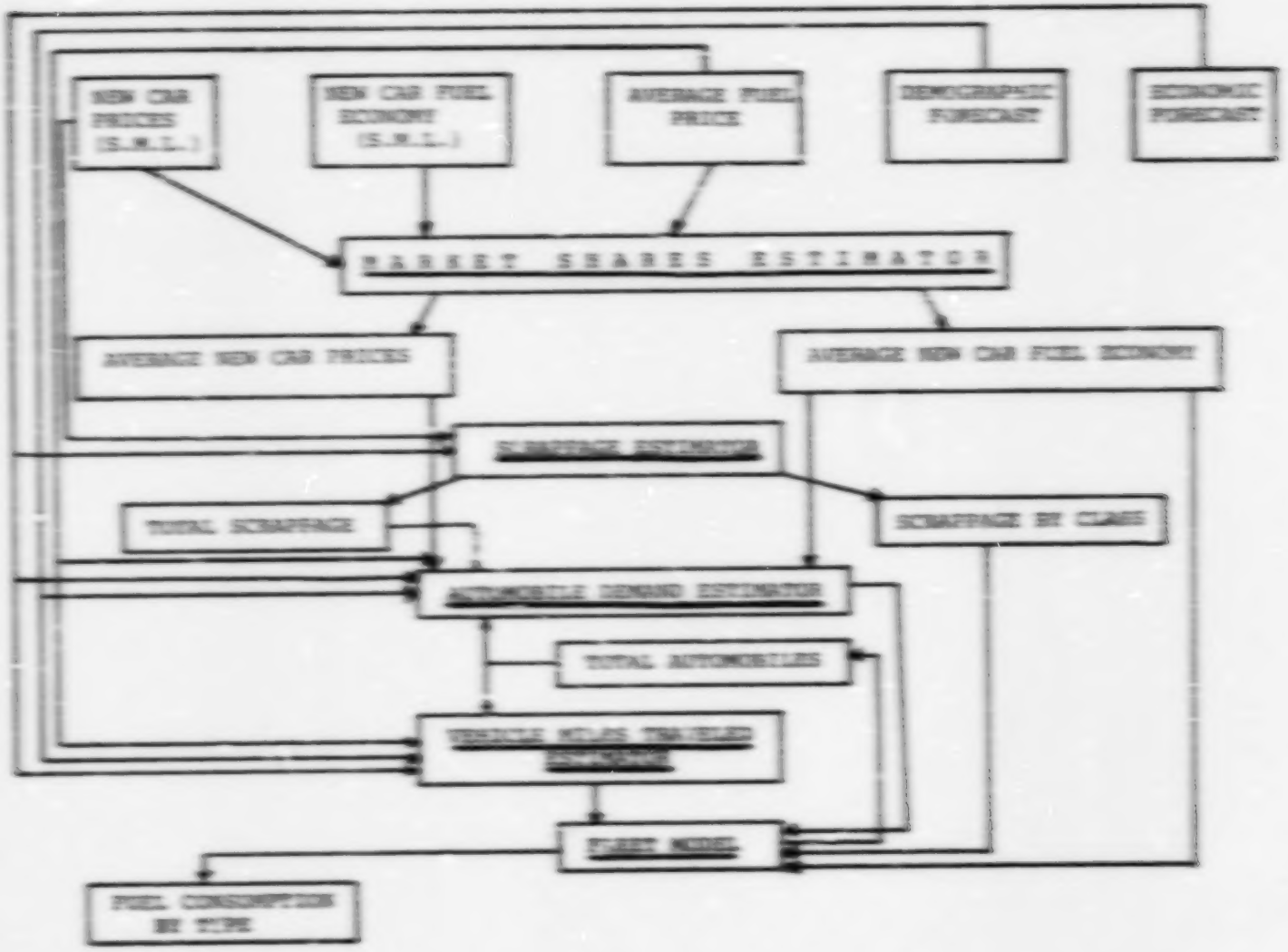
OVERALL STRUCTURE OF
MARKETING AND MOBILITY MODEL WITH
REQUIRED INPUTS AND OUTPUTS

FIGURE 2-1



produce required output variables. This structure is sufficiently broad to incorporate what are felt to be the key determinants of automobile demand and use. In Figure 2-8 the core of the Marketing and Mobility Model is identified as four "estimators." The first is a market shares estimator. Identifying a market shares estimator separately from a total automobile demand estimator represents a significant modeling choice. The alternative would be to use demand by market class estimators eliminating the need to have a separate automobile demand equation. This approach was rejected for several reasons. The most important reason was the desire to account for the impact of income on automobile ownership in a credible manner. It is clear from the evidence examined (Section 2.3) that income will be the most important variable affecting automobile demand in the long term. If time series regression is used to estimate the impact of income on automobile ownership, there is likely to be correlation of all secular trends affecting automobile ownership with income since income is highly correlated with time. Since most of these secular variables could not be included in a time series regression relationship, there would be a strong likelihood of multicollinearity bias on the parameter for income. Therefore, a cross-sectional relationship was used to estimate the impact of income on automobile ownership. This relationship

FIGURE 2-8
MARKETING AND MOBILITY MODEL STRUCTURE



was already discussed in Section 2.1 and will be elaborated below. In order to incorporate this income-ownership relationship in an estimator of new car demand, it was necessary to have a single equation for new car demand rather than three separate equations. The historical data on the number of cars of each size class in the fleet were not available. This single demand equation would be driven by average characteristics of new cars (price, fuel costs) as weighted by the sales mix of new cars. This sales mix would be determined by the relative characteristics of new cars in each market class.

In addition to data on average new car characteristics, fuel prices, economic indicators and demographic variables, the new car demand estimator should also account for the size of the automobile fleet and number of cars scrapped each year. For reasons outlined above (2.4, Factors Which Influence Scrappage) it is desirable to estimate the impact of new car characteristics on the scrappage of existing cars. Given that a scrappage estimate would be available, consistency would require that the new car sales estimator be sensitive to endogenous scrappage estimates.

Returning to Figure 2-8, the "Automobile Demand Estimator" receives both direct input variables (exogenous economic and demographic forecasts and fuel price forecasts) as well as endogenous variables produced by the "Market Shares Estimator" (average new car prices and fuel economy) and the "Scrappage Estimator" (automobiles scrapped).

The "Vehicle Miles Traveled Estimator" relates to the automobile estimators (market share, total sales, and scrappage) via the total number of cars on the road and their average characteristic (fuel economy). These variables require a fleet model since the behavioral estimators are only providing year to year flows, not stocks. The fleet model is an a priori relationship which keeps account of the flows and enables one to determine characteristics of the stock. These characteristics should include: average age, age distribution, average fuel economy, fuel economy by age group, distribution of miles traveled by age group, an accounting of the distribution of size classes and "technology families," and finally total fuel consumption (by fuel type). The last variable, fuel consumption, requires an estimate of total vehicle miles traveled in addition to the flow data on automobiles by type.

The "vehicle miles traveled estimator" requires, in addition to data on the automobile stock, economic, demographic, and fuel cost forecasts.

Simultaneous Estimation

At the outset it should be acknowledged that a system such as identified in Figure 2-8 should be simultaneously estimated. Variables which are endogenous to one "estimator" are exogenous to another. Failure to estimate such a system simultaneously may result in bias of some or all parameter values. The data base, however, does not allow simultaneous estimation because too few observations were available. The data on automobile purchase behavior is drawn from Automotive News Almanac based on compilations by R. L. Polk. This data provided only fourteen observations between 1960 and 1973. This number of observations is adequate for single equation estimation but insufficient for simultaneous estimation of three equations. Too many degrees of freedom are "used up" in simultaneous estimation leaving too few degrees of freedom to establish significant parameter estimates. Until new data are developed with for

more observations than are currently available, simultaneous estimation will not be possible.

Generalized Price

Certain other factors influencing new car sales such as new car prices, fuel economy, and the price of gasoline, have been combined to form a single "generalized price" variable. This step was dictated by the very high correlation between the above three variables (simple correlation coefficients of .9 or greater) and the concomitant multicollinearity problems that occur when 2 or more of the variables appear separately in a single equation. The formula used for the generalized price is:

$$P^g_t = (P_{new}) + 52.851\ (MCPM)$$

where P^g_t is the generalized price; (P_{new}) is the real, constant dollar price of new cars; (MCPM) is the real, constant dollar gasoline cost per mile of driving new cars and is equivalent to the ratio of the real, constant dollar price of gasoline per gallon to average new car fleet

miles per gallon; and 52,851 is a scale parameter. This scale parameter represents the discounted, perceived lifetime mileage of new cars. The miles per year of life implicit in this term were drawn from Nationwide Personal Transportation Study results; an annual discount factor of 15 percent was applied to mileage in future years; and a perception factor of .8 was multiplied by total discounted lifetime mileage to reflect incomplete consumer awareness of lifetime mileage costs.

In short, the generalized price concept permits variables which present multicollinearity problems to be collapsed into a single variable, thus maintaining sensitivity to automobile prices, fuel prices, and fuel economies.

Market Share Estimator

The ability to make reasonable and reliable forecasts of the new car market shares held by various classes of automobiles adds an important dimension to automobile market projection, for a model that begins and ends with simply new car sales is in effect assuming that user and consumer

adjustment to changes in policy-sensitive variables (i.e., new car prices, gasoline prices, and fuel economy) is reflected solely in the number of new cars purchased--an assumption which is both at variance with real world experience and which makes results insensitive to a key source of potential gasoline savings, namely shifts to more fuel-efficient vehicles.

In an effort to bridge this gap, several recent studies have attempted to construct a market shares model. Rand Corporation has constructed a heuristic automobile fleet mix model to complement its econometrically estimated New Car Sales/Automobile Ownership/Vehicle Miles Traveled (NAV) model (64). The fleet mix model is linked to the NAV model via aggregate annual new car sales and the overall rate at which automobiles are retired from the fleet--both outputs of the NAV model--but is otherwise dependent upon arbitrary assumptions concerning the fraction of annual production taking place in particular classes, and employs a correction factor to adjust for differences between the anticipated rate of scrappage from NAV and that based upon past experience. Because it assumes that the demand for new cars, by shares, is set exogenously, this heuristic fleet mix model is not particularly suitable for forecasting purposes.

Explicit estimation of five equations for predicting actual market shares of five different classes of automobiles was done by Chase in their study, The Effect of Tax and Regulatory Alternatives on Car Sales and Gasoline Consumption (12). Five separate equations were fitted for five different classes of automobiles using a logit formulation of the form

$$P = \frac{e^A}{1+e^A}$$

where

P = the market share of some class

A = a linear combination of explanatory variables for that class.

Such a formulation insures that the predicted shares will always be between zero and one (but not that they will sum to one).

The theoretical specifications of the TSC market shares model are identical for each of the five share equations and include variables for the "own-price" of a market class of automobile, gasoline prices, income, and urbanization. Cross sectional

data by States for 1972 were used instead of time series data because of the absence of "small cars" prior to 1959, the absence of 'intermediates" prior to the mid-1960s, little variation in gasoline prices over time, and a desire to avoid the hedonic price problems for new cars. Use of cross section data is fraught with its own problems, however, the most notable of which is relative lack of variation in new car prices across States. Because titling or sales tax rates do vary widely across States (between 0.9 and 7.1 percent) this variable was used as a proxy for the "own-price" of an automobile class. Apparently, however, even this proxy does not have sufficient variation since none of the estimated coefficients for the initial tax or registration rate could be considered significant except at a 30 to 40 percent level of error. Moreover, since such a tax rate does not vary between classes of automobiles, cross-price elasticities cannot be estimated, and one is left with the same logical inconsistency as that found in the Chase model, i.e., a variable that affects the share of one class of car must simultaneously be affecting the share of one or more other classes in an opposite fashion, since the net change in all classes must be offsetting.

The market class structure which was used for estimation has already been discussed (2.6, "Determination of Market

classes"). The reader should recall that inertia weight was used to establish market classes but future cars' classifications are not constrained by weight. The weight index estimated to best approximate the "roominess index" market classification system is:

Class	Weight Index
Small	Under 3050 lbs
Medium	3350-3500 lbs
Large	Over 3500 lbs

The market shares model developed in this study also uses a logit formulation for purposes of estimation. However, separate equations were not independently estimated for each of the three automobile classes: small, medium, and large. A system of three dummy variables interacting with the three price variables for each class was used to link the various shares and price observations in such a way that only a single equation need be estimated, while maintaining identifiability of the separate coefficients for each of three market share equations. This particular format for estimation was dictated by the small number of reliable market share observations available (from eleven years) versus the relatively large number of coefficients

to be estimated in each equation (five). Total degrees of freedom in the system may be increased by collapsing separate vectors of observations on the three class market shares into a single vector.

The single equation estimating form (using a logit transformation) may be algebraically expressed as follows:

$$\ln \frac{P_t^c}{1-P_t^c} = a_0 + a_1 (D_1 X_t^S) + a_2 (D_1 X_t^M) + a_3 (D_1 X_t^L)$$
$$+ a_4 (D_2 X_t^S) + a_5 (D_2 X_t^L) + a_6 (D_1 X_t^M)$$
$$+ a_7 (D_2 X_t^M) + a_8 (D_1 X_t^L) + a_9 (D_2 X_t^L)$$
$$+ a_{10} (D_1 P_{t-1}^c) + a_{11} (D_2 P_{t-1}) + a_{12} (D_3 P_{t-1}^c)$$

where

P_t^c = the market share of a class c at times t (c - small, medium and large)

X_M^S = the price of small cars, times t

X_t^M = the price of medium cars, times t

X_t^L = the price of large cars, times t

D_1 = Dummy variable with a value of one for small car observations; zero otherwise

D_2 = Dummy variable with a value of one for medium car observations; zero otherwise

D_3 = Dummy variable with a value of one for large car observations; zero otherwise

(P^C_{t-1}) = The previous year's market share

$a_0, a_{11} \cdots a_{13}$ = coefficients to be estimated.

The coefficient estimates for the market shares model are as follows:

$$\ln \frac{P^C_t}{1-P^C_t} = -4.1749 - 1.8660(D_1 X^S_t) - 2.0765(D_2 X^M_t)$$
$$(-3.9858) \quad (-1.7728) \quad (-.6095)$$
$$-.4299(D_3 X^L_t) + 3.5450(D_2 X^S_t) + 3.5093(D_1 X^M_t)$$
$$(-.2651) \quad (2.3773) \quad (2.1158)$$
$$+ 1.8117(D_3 X^M_t) + .2589(D_2 X^L_t) + 5.6438(P^C_{t-1})$$
$$(.9024) \quad (.1103) \quad (5.5060)$$

$R^2 = .9473$

S.E.E. = .2201

D.W. = 2.1907

d.f. = 21

The data used for estimation are annual observations spanning the years 1963-1973. Vehicle classifications and the corresponding data on market shares and new car prices by class are derived from detailed sets of data compiled from Automotive News Almanac. It should be pointed out that in this estimated equation, the price variables used are actually the real generalised price of each automobile class relative to that of all new cars sold. The generalised prices by class are constructed in exactly the same fashion as described above, except, of course, different prices of new cars and fuel efficiencies by class of automobile are used. Each share equation is thus sensitive to its own price, its own fuel efficiency, and the price of gasoline as well as the prices and fuel efficiencies of adjacent classes.

It may be noted that all coefficients are of the theoretically correct sign: "own-price" variables have negative coefficients while "cross-price" variables have positive coefficients. Two cross-price variables, small car prices on large automobile shares, have been omitted from the final specification because they almost invariably appeared with perverse signs and extremely low t-statistics. It was assumed, therefore, that the

price elasticities between non-adjacent shares was zero. Also, the lag structure for market shares has been constrained to be the same for each class of automobile simply by virtue of the fact that such a lag structure performed better than the unconstrained version. Finally, although the estimated own-price coefficients for medium car shares and large car shares are only significant at a 25 percent and 40 percent level of error respectively, they are retained nonetheless under the reasonable theoretical belief that market shares are in fact affected by the prices of vehicles in that class. The cross-price coefficient for large car prices on medium car shares is thus also retained for logical consistency with the effect of large car prices on the large car market share.

The three separate market share equations in their final form are as follows:

$$S_t = \frac{1}{1+e^{-(-4.1749-1.8660(X_t^S)+3.5893(X_t^M)+5.6428(S_{t-1})}}$$

$$M_t = \frac{1}{1+e^{-(-4.1749-2.0769(X_t^M)+3.5450(X_t^S)+.2589(X_t^L)+5.6428(M_{t-1})}}$$

$$L_t = \frac{1}{1+e^{-(-4.1749-.4299(X_t^L)+1.8117(X_t^M)+5.6428(L_{t-1})}}$$

Fitted values of market shares from the three final form equations are guaranteed to fall between zero and one as a result of the logit formulation. However, there is no assurance that the projections of the three shares will sum exactly to one in spite of the interdependence of the three equations which are linked by cross-price sensitivities.* For this reason, ex post normalization of the shares must be carried out by dividing each share by the fitted total, thus preserving the projected relative magnitudes of market shares between classes while scaling all three to sum to unity.

* One advantage of using a single estimating equation to estimate a system of interrelated equations is that constraints between variables of different equations may be imposed upon estimation, i.e., one might theoretically be able to impose a constraint among market share equations which would insure that a change in one class share pursuant to a change in one of its explanatory variables is exactly offset in an equal fashion among one or more other class shares, thus generating

(continued on next page)

Automobile Demand Estimator
Review of Previous Models

Since roughly 1956-1957, most automobile demand models have evolved from the basic Chow and Nerlove stock-adjustment models. Thus, for the most part, a literature review can describe increasing econometric sophistication by a chronological discussion beginning with those papers. However, some mention should be made of three earlier studies which helped define the automobile demand problem.

One of the first automobile demand studies, conducted by Ross and Von Szeliski was published in 1939 (48). This model divides automobile demand into two components, new ownership demand

market share predictions that would sum to unity--clearly a more satisfying result than simply confining specifications to reflect (imperfectly) negative (or positive) reactions in one or more market shares given a change in some variable that we know must logically be taking place upon a positive (or negative) reaction to that same variable change in some other share. One such constraint was attempted within the framework of the above estimating equation. Though significant coefficients of the theoretically correct signs and an overall good fit were obtained, the fitted market shares did not sum to unity and hence, ex post normalization was still required. Since the degree of normalization required was not substantially less than for the equation presented here, and since there was the possibility of some simultaneity in the constrained estimated form, the presented unconstrained results were judged to be our best and most reliable estimates in spite of the inherent "uneven" reciprocal reactions to variable changes among shares.

is estimated with reference to the rate at which ownership levels approach a saturation level; replacement demand depends on the rate of used car scrappage. Rose and Von Beelitski estimate price elasticities from several different data sets and generally find the price elasticity estimates to lie in the range -1.0 to -2.0.

In his elaborate 1954 automobile demand model, M. J. Farrell (21) focuses on the interrelationship between new car demand and the prices of substitute used-car goods. With six used car categories, plus new cars, Farrell models a system with seven interrelated endogenous variables. Farrell does not set up his model in such a way as to estimate either price or income elasticity.

As a final precursor of the mature stock-adjustment model, Kenneth Boulding (5) in 1955 demonstrated the central importance of the size of the existing automobile stock relative to the demand for cars. Boulding focused on the important relationship between used car scrappage and new car sales and on the effects of distortions of the age distribution of the American automobile population. Using automobile sales data

from R. L. Polk and Company Automobile Facts and Figures. Boulding projects new car sales into the future. In light of the lack of domestic automobile production during most of World War II, and the enormous pent-up demand in the years following, Boulding predicted an echo effect of high automobile demand in the early 1950's due to the scrappage of the post-War cars.

Two years later Gregory Chow published Demand for Automobiles in the United States (13), in which automobile demand was specified in the following general way, which has since been widely copied. Chow assumes that:

1. The desired stock of cars depends on economic and demographic variables.
2. The speed at which actual stock adjusts to desired stock is a linear function of their difference.

Adjustment to equilibrium desired stock is not considered to be instantaneous because of uncertainty about the level of targeted demand, because of transaction costs, and because

of decision and purchasing lags. From the two relationships described above, a reduced form equation is estimated from which can be derived the elasticities of car demand with respect to the exogenous economic variables as well as the speed of adjustment from actual to desired stock.

Crucial to empirical parameter estimation is aggregation of the heterogeneous collection of existing automobile of different ages. Chow does this by weighting existing age distributions by current prices as reflected in advertisements to give the 'number of new car equivalents per capita.' Chow assumes that automobile demand expressed in physical units depends primarily on the existing stock of automobiles, car prices, and income. Chow experiments with both real disposable income and a measure of permanent income, which he finds works slightly better. Chow also experiments with an asset demand aspect of new car demand by including money supply, an alternative asset, as an exogenous variable in some specifications of the demand for new automobiles. After estimating the parameters of several models intended to predict new car sales, Chow chooses the following as the one that performs best:

$$g' = .0779 + .0201p - 1.2310R_{t-1} + .0117I_d$$
$$\quad (.0026) \quad (.0472) \quad (.0011)$$
$$R^2 = .959$$

where

g' = per capita new car purchases, physical units

p = price index for all cars, new and used

R_{t-1} = stock at beginning of year, in dollars

I_d = per capita disposal income, deflated

Chow measures price and income elasticities as long-term elasticities, the change in total desired automobile stock. Depending on the demand formulation, Chow finds that the income elasticity of demand for cars is in the range 1.16 to 2.93 and the price elasticity -0.78 to -1.56. These Chow estimates are based on a time series analysis using data for the years 1921-1953. At the present time, with the car generally considered more of a necessity, the price elasticity could be expected to be somewhat lower.

At about the same time Chow was publishing his automobile demand model, Merlove published a similar model in the Journal of Marketing (65) in response to a forecast proposed

by Hans Brems [7]. Brems had described long-term trends in automobile demand as a dependence on new owners and replacement owners, without regard to cyclical or price influences. Nerlove replaces the assumption of Brems that the stock is always at equilibrium with an assumed stock-adjustment process.

While the Nerlove parameter estimates yield a long-run price elasticity of -1.2 and income elasticity of 1.8, the same parameter estimates yielded an annual depreciation rate of 45 percent. While Nerlove seems to win the theoretical debate as to the proper general specification form of automobile demand, his particular estimates are not believable. This is probably because automobile demand depends on more than pure price and income variables. In fact, cyclical economic variables are now considered of paramount importance in estimating the demand for new cars. Similarly, the price of gasoline and the price of used cars can be presumed to influence new car sales. With regard to Nerlove's price elasticity estimate, Brems writes, "As regards automobiles, their relative price has changed so little over time that even Roos and Szalishi, in their ambitious and authoritative analysis of automobile demand, decided to drop it entirely as a variable."

Trouble similar to that of Nerlove seems to have afflicted Houthakker & Taylor (28) in their estimation of automobile demand functions in a larger study of consumer demand for many categories of consumer goods. Letting q's be consumer purchases, X's be consumer income, and P's being relative prices for each consumer goods category, Houthakker & Taylor regress the equation

$$q_t = A_0 + A_1 q_{t-1} + A_2 X_t + A_3 X_{t-1} + A_4 P_t - A_5 P_{t-1}$$

This is a reduced form of a larger demand system set up in such a way so that from the A estimates Houthakker and Taylor can retrieve short and long term income and price elasticity estimates, the strength of habit formation, and the depreciation rate. This method is very clean in that it yields substantial results with no required aggregation of the existing stock of goods at any time.

Houthakker & Taylor use expenditure data published by the Office of Business Economics and Personal Consumption Expenditure rather than income, per se, as the X variable. They use adjusted BLS price figures. While their elasticity

estimates from their first edition (1966) have been widely catalogued in discussion of automobile demand, conclusions of the 1970 second edition clearly state the authors' lack of confidence in their approach as a means of understanding automobile demand. Their final single-equation model leaves out price completely because "the price elasticities were negative but insignificant when the relative price of automobiles was included in the model" and, moreover, for automobiles "the PCE elasticity was implausibly high." While their initial study was of post 1929 years, data on the post-War period also gives statistically insignificant price elasticity estimates.

With the realisation that most new car buyers contract to borrow money to pay for new automobiles rather than pay the purchase price all at once, Daniel Suits (91) introduced a variable into the automobile demand specification to reflect credit conditions. The price variable becomes a variable Suits devises to approximate the average monthly payment for a new car. Suits uses the first differences method to deal with auto-correlation. Although the auto-correlation present in the model does not bias the estimates, it does produce inefficient coefficient estimates. Suits claims that the credit condition is so important, that, if it is not included,

the price elasticity of demand for new cars becomes a positive +.40. The elasticity of monthly payment is a more plausible -.58. While Suits estimates an elasticity of demand with respect to real disposable income of 4.16, this high figure can be explained by the fact that Suits did not measure sales on a per-capita basis, failing to take into account substantial population growth. This improper specification biases the income elasticity estimate upward.

While Suits measured automobile sales on an annual basis in physical units, Hamburger (26) later inserted interest rates into a quarterly model explaining dollar sales. Hamburger specifies a standard stock adjustment model, but with lagged exogenous variables. Using AA bond rates as a measure of the interest rate, Hamburger finds that interest rates changes take four to six months to have their maximum effect on car sales. This is because bank credit condition changes take some time to be reflected in credit condition toward car buyers. Hamburger estimates a price elasticity of -1.17, an income elasticity of 4.32, and an interest rate elasticity of -.85.

Michael Evans (20) also includes credit conditions, as well as income, price, used car stock, and the unemployment rate in

his single equation automobile demand model published in Macroeconomic Forecasting. Evans arrives at a particularly high price elasticity estimate of -1.5 and a long-run income elasticity of 1.2.

With the realisation that econometricians have not been able to forecast the demand for automobiles as accurately as the demand for other consumer goods, and that the purchase of an expensive durable such as an automobile logically depends on consumer expectations about future economic conditions, several economists have recently investigated the use of surveys of consumer sentiment as a tool. In a 1970 Brookings paper Saul Hymans (29) compared the results of forecasts using objective economic variables and those using consumer sentiment. While surveys of consumer sentiment are useless in long-term forecasts because consumer sentiment cannot be predicted on a long-term basis, it might be of help in forecasting two quarters ahead.

If consumer sentiment is closely related to economic variables, the use of consumer sentiment should add little to an "objective" explanation of the demand for automobiles. Using consumer sentiment indices from the University of Michigan Survey

Research Center, Hymans finds that roughly 80 percent of the variance in consumer sentiment can be explained by four real variables. These variables are a measure of lagged real income, the rate of increase of common stock price in the preceding quarter, the rate of increase of a four quarter average of common stock prices, and the ratio of consumer prices to an eight quarter average of consumer prices. In the simplest automobile demand models Hymans found that consumer sentiment could explain car sales about as well as income.

Hymans then tested a more complicated and sophisticated stock adjustment model including income, unemployment rate, and consumer sentiment (in addition to other exogenous variables). Hymans found that in an unadjusted form consumer sentiment proved to be a statistically insignificant determinant of automobile sales. However, by filtering out all but the largest, most sustained movements in consumer sentiment, (all but 17 of 60 quarterly values 1954-1968), Hymans finds that consumer sentiment does have an independent effect on car sales.

of interest to this review Hymans finds a short run (one quarter) price elasticity of between -.78 and -1.17 and a long-run price elasticity of between -.10 and -.46. Hymans finds a short-run income elasticity of between 0.55 and 1.00 and a long-run income elasticity of between 1.01 and 1.06. This model is different from many others in that long-run elasticities are smaller than short-run elasticities. One would expect that a consumer sentiment focused model would emphasize transitory changes in economic variables.

A similar approach, using consumer sentiment data, was tested by F. Thomas Juster and Paul Wachtel (10). Their results are similar to Hyman's in that they find an "anticipatory" model to be a good substitute for an "objective" model and that adding anticipatory variables to the objective economic variables reduces the residual errors in predictions of new car sales. The Juster and Wachtel results emphasize the importance of credit conditions, and note that they find that changes in the "maturity on installment credit contracts" perform better than interest rates.

Juster and Wachtel experiment with several different demand equation specifications in their "objective" quarterly model. Since they deal with permanent and transitory income rather than current income, their elasticity estimates are not strictly comparable to those of other studies. They do, however, estimate conventional current-income, price, and payment maturation elasticities from the model. They estimate the income elasticity to be 1.15, the price elasticity to be -.56, and the credit maturity elasticity to be .27. They emphasize, however, that they believe a model emphasizing transitory income and employment movements to be more realistic.

Two recent models should be mentioned which are not strictly stock-adjustment models. These models assume that new car sales are influenced by the price of new cars relative to the price of the substitute good, used cars. The stock of used cars in existence is assumed to influence new car sales only indirectly, through its influence on used car prices. While these models are appealing because they do not require direct automobile stock aggregation, the models require data on used car prices which are difficult to forecast but necessary to use the model for new car demand forecasts. Nevertheless, the models do yield price and income elasticities.

Frank Wykoff (66) holds the view that new and used cars must be treated as separate commodities rather than substitutes which can be easily aggregated. He calls the model a "superior goods" model. Rather than using price data as the cost of owning a car, Wykoff adopts the concept of user cost or rental cost, where the one year cost of owning a car is the opportunity cost of holding the car--the price times interest rate, plus the annual depreciation of the car. The demand for new cars is then said to depend on the user price of used cars, the user price of new cars, the consumer price level, and income. The price of used cars can be either fit directly into the equation or estimated, (though Wykoff's estimates fit the actual prices poorly), from data on income, real new car price, and used car stock. Wykoff estimates a current income elasticity for cars of about 1 and a rental price elasticity, influenced by interest rates, in the neighborhood of -.3 to -.4. Fitting his data into a conventional stock-adjustment model Wykoff finds that the superior goods model performs better.

Mention should also be made of the Rand Model designed by Wildhorn, Hunright, Enns, and Kirkwood (64). This is an annual multi-equation forecasting model used to project

automobile and gasoline demand using data from 1950 to 1972. The sales level of new cars per household is assumed to depend on price of new and used cars, the yearly change in real income, and a strike dummy. The new car demand equation is:

$$N = -.5080 - .20869Pn + .09318Pu$$
$$\quad (1.984) \quad (5.512) \quad (1.632)$$
$$+ .73050 \quad (Y_t/Y_{t-1}) + .01733\ S$$
$$\quad (2.757) \quad (3.406)$$
$$R^2 = 0.66 \quad D.W = 2.75$$

In the Model N stands for annual new car sales per household, Pn is an index of real new car prices, Pu as index of real used car prices, Y is a measure of permanent income per household, and S is the strike dummy for strikes in the automobile industry.

This study finds a price elasticity of demand for new cars to be -1.14 before used car prices adjust to the higher price of the substitute good, but the longer-run price elasticity of demand for new cars is estimated at -.32. The authors also estimate a short-term elasticity of demand for new cars with respect to the price of gasoline of -.56 which is considerably higher than other estimates.

This review has established a range of price and income elasticities with which to evaluate the consistency of the Marketing and Mobility Model parameters. Also the more recent studies have indicated that credit availability, operating costs, and the used car market are all important variables with which to explain automobile demand. While credit availability is not a variable which is particularly useful for long term forecasting (since it itself cannot be readily forecasted), the used car market and operating costs are clearly important elements for the Marketing and Mobility Model to include.

Marketing and Mobility Model Automobile Demand Estimator

The fundamental concept used to specify a new car sales model for the purpose of forecasting to the year 2000 is that of short-run stock adjustment, though not partial stock adjustment as used in its classic form by Chow (1), Nerlove (6),

Houthakker (26), and others.[9] Adjustment in this model occurs due to a gap between a 'target' stock of automobiles, O_t^*, and

[9] The "classic" partial stock adjustment mechanism referred to is one in which adjustment takes place from some existing stock to some actually desired level of stock, given current levels of income, prices, and /or any other determining variables. Such a model for new car sales would be specified linearly as follows:

$$(1) \quad A_t^* = \alpha + \beta Y_t + \gamma \underline{P}_{t-1}$$

$$(2) \quad N_t = \lambda(A_t^* - A_{t-1}) + \delta A_{t-1}$$

where A_t^* is the desired stock of automobile, Y is income, $\underline{P}$ is a vector of other explanatory variables, such as prices, fuel economy, etc., N is new car sales for the year t, A_{t-1} is the stock of cars on hand as of the end of the previous year, and δ is the fleet rate of scrappage. The coefficient λ is the adjustment coefficient and may take a value greater than or equal to zero, but less than or equal to one. In the special case where λ is constrained to equal unity, we would have an adjustment model for the long run in which we assume that actual ownership has approached and equaled desired ownership. Assuming an historical rate of scrappage has been predetermined, estimation in this case simply amounts to estimating the coefficients for the desired ownership specification.

In the case where λ is less than unity, the model may be put into its reduced form by substituting equation (1) into A_t^* in equation (2), multiplying through by λ, and collecting terms. One thus obtains:

$$(3) \quad N_t = \alpha\lambda + \beta\lambda Y_t + \alpha_1\lambda\underline{P}_t + (\delta - \lambda)A_{t-1}$$

as the equation to be estimated. Given *a priori* knowledge of the value of δ, unique, estimates of all the other parameters may be determined from the estimated coefficients.

Nerlove (45) offers an interesting variation of this partial stock adjustment model that includes lagged values of the explanatory variables. In effect, equation (1) might best be considered as but a special case of Nerlove's specification--one in which it is *a priori* assumed that no lag structure exists in the determination of new car sales.

the 'existing' stock of automobiles as of the end of the current period, proxied in this model by the stock of cars on hand as of January 1 of the current year less the number of automobiles scrapped over the year (data on these variables are compiled by R. L. Polk and are presented in Automotive News Almanac, various issues). The rationale for this structure is discussed below.

A variety of data sources spanning thirteen years show considerable similarity in the relationship between automobile ownership and real income. Table 2-60 presents the results of regression analyses in which the same functional form was applied to various automobile ownership by income data sources. Linear and semilogarithmic forms were also tried, but the log-linear form shown provided the best fit.

Some of the basic spending units implicit in data sources analyzed in this fashion were households, others were families. Because of the household formation implications of the post-War 'baby-boom' and recent declines in the fertility rate, the household basis was felt, for purposes of long-term forecasting, to be a better reflector of the changing composition of the population than was the family. For consistency with this basis, as well as for representativeness among the sources analyzed, we chose 1972 Consumer Buying Indicators as a basis for our mechanism for incorporating

TABLE 2-48 AUTOMOBILE OWNERSHIP/INCOME RELATIONSHIPS: LOGARITHMIC, 1958 DOLLARS

[Estimating Equation: Log Y = a + b log x]

$(Y = 10^{a}x^{b})$

Source and Year	Number of Income Categories	[Illegible] Coefficient a	[Illegible] Coefficient b	Standard Deviation a	Standard Deviation b	Percentage Number of Deviations	R	R^2	t Ratio
P.I. Number of Consumer Units:									
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P.I. Metropolitan Personal Transportation: [illegible]									
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P.I. Cars per Family Occupied:									
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P.I. Persons per Family Unit:									
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Income Groups: [illegible]

the income saturation effect. This curve is described by the equation

$$\text{Auto ownership per household} = 0.01786\ (\text{Income})^{.4741}$$

and has the general shape of the patterns shown in Section 2.1 ("Factors Which Influence Automobile Demand").* It reflects a gradual tapering off of additional automobile ownership with income. This structure could, theoretically, lead to automobile ownership in excess of one car per licensed driver. In fact, the automobile ownership of the highest income group upon which the figure is based has an average automobile ownership of 1.9 compared to an average of about 2.1 driving-age persons per household. For this reason, we have not attempted to extrapolate this curve beyond its range of calibration, but instead have assumed that it flattens out at that point, as does the curve presented in Section 2.1.

One of the chief reasons for incorporating the income saturation effect described above is that, as the distribution of the population by income group shifts toward greater affluence in the coming decades, this form of saturation is likely to play an increasingly apparent role in shaping consumers' auto-

* Income is expressed in 1967 constant dollars.

mobile purchase decisions. Indeed, its influence is already apparent, as is evident from the fact that this relationship provides a fairly good approximation to actual automobile ownership from about 1960 on.

The "target" automobile ownership is computed from the ownership by income group equation presented above by multiplying automobile ownership per household estimated for each income group times the number of households in each group, and then summing over all groups. The gap between target and actual ownership in any year is then computed as the difference between the target ownership and the actual ownership, plus vehicle scrappage occurring during the year. This gap term is then combined with a price term to estimate new car sales

This process is short-run in its specification in that no attempt is made to constrain new car sales in any one year to match exactly the gap between the target level and actual ownership. It also differs from the traditionally used stock adjustment models in three major respects:

(1) The adjustment parameter(s) is not constrained to lie between zero and one, and thus, the possibility is admitted for new car sales to be greater than the "gap" under certain circumstances;

(2) Adjustment to the "gap" need not occur in a strict linear fashion, but may be subject to non-linear influences stemming from consumer behavior towards percentage changes in the "gap" independently of changes elsewhere in other factors determining new car sales.

(3) The "gap" reflects two distinct explanatory variables which influence new car sales independent of influences from other explanatory variables.

Point three is particularly important with respect to the remainder of the automobile demand estimator. Since both income and scrappage are explanatory variables which determine the "gap," it would be redundant to include these variables elsewhere in the estimator. This also applies to used car prices since it is a variable which directly influences scrappage. As the Rand model (64) determined, new car prices influence used car prices and used car prices influence scrappage. With respect to new car demand, used car price, and scrappage variables would be redundant since the scrappage estimate accounts for the impact the (exogenous) new car price variable has on used car prices and on

scrappage. With respect to scrappage, used car prices would be an unnecessary explanatory variable since they are determined primarily by new car prices. If new car prices are included in the scrappage estimate, the used car price variable need not be used. It would make sense in the context of simultaneous estimation to include separate scrappage and used car price estimates since these are both endogenous variables. In that context there would be an equation for new car demand, used car prices, and scrappage with used car prices being an endogenous independent variable in the scrappage equation and the new car demand equation. In a recursive framework, all of the exogenous variables (especially new car prices) which determine used car prices are already contained in the new car and scrappage estimators.

The final form of the new car sales estimates was:

$$N_t = 286,721.3(\theta_t^e - (Autos_t - D_t))^{.2178}(R_t^e)^{-1.7039}$$
$$(1.83249) \qquad (1.0370) \qquad (-3.8616)$$

$$R^2 = .7807$$

$$S.E.E. = .0417$$

$$D.W. = 1.177$$

$$d.f. = 11$$

where

N_t = Total annual new car sales in year t

O_t^* = The target ownership of automobiles for the year t

$(Autos)_t$ = The stock of automobiles on hand at the beginning of year t

D_t = Scrappage of vehicles over the course of year t

K_t^* = An index of the generalised price with 1967 = 1.

$O_t^* = (\sum_I N_I P_{It})\ HHLD_t$

P_{It} = Auto ownership per household of income I

$HHLD_t$ = Total households

I = Household income

$N_I = .01786\ I^{.4743}$

$R^2 = .981$

The relatively high apparent price elasticity of -1.7 is misleading. First, it is for the generalised price variable which includes both the cost of purchasing and operating an automobile. Second, it does not account for the feedback of the generalised price variable (K_t) on the "gap" via the endogenous scrappage estimate (D_t) which also uses K_t as an exogenous variable. The actual elasticity values with respect to new car prices and operating costs will not be constant

over time. They will be discussed below in 2.8 ("Model Summary and Sensitivity Tests").

Scrappage Estimator

It is important to determine the influence that new car prices have on the scrappage of used cars. This will be important to calculate energy savings from policies which might increase the price of inefficient new cars. One expects higher new car prices to increase the value of used cars and to reduce the scrappage rate of used cars. New car price increases in large cars only, with constant or decreasing prices for small cars (however induced), will not affect the overall scrappage rate in the same way that price increases across all cars would. However, the scrappage rate by market class would be as strongly affected resulting in substantial changes in the energy efficiency of the older vintage cars: retirements of small efficient cars with perpetuation of large inefficient cars within each vintage. Such changes could have substantial impacts on the fleet fuel economy

The second major factor determining automobile scrappage is macroeconomic conditions. Since new car sales are partly determined by the gap between desired levels of automobile ownership, last year's automobile stock and automobile scrappage (above), any macroeconomic factors which are used to estimate scrappage would also impact new car demand. Economic factors are most likely to influence the temporary postponement of marginal (i.e., older) vehicles, a consideration reflected in the scrappage model presented here by estimating the scrappage of older vehicles (eight or nine years). Early retirements are more to be due to factors not related to the macroeconomic environment or the prices of new cars. These factors can affect the prices of late model used cars, but even severe economic and new car price changes will not generally force the retirement of newer cars.

Historically, vehicles have been retired from use at a rate which increases with each additional year of vehicular life, up to about eleven years of age. At that point, the average retirement rate holds roughly constant around 30 percent per year. The average retirement history for vehicles of model

years 1957 to 1971 is shown in Table 2-49. These form the basis for the scrappage function employed within the model, though vehicle prices and economic conditions are taken into account also, as described below.

Because of the flattening out of the scrappage function for automobiles of eleven or more years of age, the average of the scrappage rates from years 11 to 14 (a value of 39.7) was assumed to hold for vehicles 16 years old and older.

To the degree that vehicle prices and macroeconomic conditions influence vehicle scrappage decisions, this influence is apt to be disproportionately felt by older vehicles. Most scrappage is attributable to vehicles nine or more years old. Even a proportional change in the scrappage rate for each age of vehicle would result in greater absolute changes among the older vehicles since a greater percentage of those vehicles are scrapped each year. To the degree that economic factors lead to temporary postponements in scrappage among marginally economic vehicles, the cars most likely to be affected will be found among the oldest segments of the automotive stock.

TABLE 2-49 -HISTORIC SCRAPPAGE OF THE AUTOMOBILE FLEET, BY AGE OF VEHICLE
(model year M)

Calendar Year	Percentage of Vehicles Scrapped during Year	Percentage of Vehicles Still in Use at End of Year
M	0.00	100.00
M+1	0.20	99.80
M+2	0.55	99.25
M+3	1.05	98.21
M+4	2.01	96.23
M+5	3.47	92.90
M+6	6.02	87.03
M+7	10.16	78.45
M+8	15.70	66.12
M+9	21.46	51.93
M+10	26.00	38.43
M+11	28.80	27.33
M+12	30.15	19.00
M+13	30.00	13.56
M+14	29.17	9.46
M+15	29.29	6.69
M+16 & after	29.70	

Sources: *Automotive News, 1976 Almanac Issue, based on model years 1951 and after. Calendar year figures are computed by linear interpolation from the cumulative distribution of survivors.*

To isolate the effect of economic conditions on vehicle scrappage, one would ideally examine their effect on each vintage of vehicle individually. Unfortunately, because of the number of parameters implicit in such an approach, many years of vehicular history would be needed, and estimates based on distant automotive scrappage history are apt to be biased because of durability changes and shifts in consumption patterns which have evolved in recent years.

Instead of a process which alters the scrappage function for each vehicle age group individually, the approach presented here examines in aggregate that group of vehicles where most scrappage occurs--namely, vehicles nine or more years old. All vehicles in this group were combined for purposes of estimation and their scrappage rate was formulated as a function of new car prices and the unemployment rate.

Scrappage might be expected to vary with new car prices for several reasons. As new car prices rise, new cars become less accessible, creating a tendency to postpone new car purchases and to "make-do" with existing stock. Alternatively, as discussed elsewhere in this report, new car prices are

positively related to used car prices so that a rise in new car prices leads to a rise in used car prices and changes the economics of consumer repair/replace decisions.

The unemployment rate was included because, *a priori*, it was expected that temporary shifts in macroeconomic conditions were likely to have a strong influence on whether consumers made their automobile purchases ahead of or behind the normal schedule. The unemployment rate seemed to be among the most visible and volatile of the cyclical macroeconomic variables, making it a logical choice to serve as a barometer of prevailing economic moods. The equation estimated for scrappage as a function of new car prices and the unemployment rate, based on experience since 1961, is shown below:

$$\begin{array}{lll} \Delta PH_t = 0.00077 & -0.070633\ (P_n)_t & -0.015519\ U_t \\ \quad (0.056) & \quad (-1.911) & \quad (-3.052) \end{array}$$

$$R^2 = .6587$$

$$S.E.E. = 0.01566$$

$$D.W. = 1.9087$$

$$d.f. = 10$$

where

SPG_t = scrappage rate for vehicles nine or more years old, year t

$(P_n)'_t$ = index of real prices of new cars in year t, 1967 = 1.00

U_t = unemployment rate, year t

The signs of both variables in the above equation appears rational: that is, an increase in new car prices tends to diminish scrappage of old cars, and an increase in the unemployment rate also tends to diminish scrappage.

The above equation is used to adjust the average scrappage rates tabulated earlier. The mean scrappage rate for vehicles nine or more years old is:

$$\overline{SPG} = .2880??^{1}$$

The scrappage rate for a particular year is S_t as computed from the estimated equation. The ratio $SPG_t/\overline{SPG}$ is of actual to average scrappage. It is multiplied by the scrappage rates

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[1] This is a weighted average based on experience from 1961 to 1971. It should not be confused with the linear average which can be constructed from the entries in the scrappage table.

for vehicles of nine or more years of age, which were tabulated earlier.

The procedure described above is applied individually to each market class. This allows unusual price changes in any single class to be reflected by retirements in that class only. For example, large increases in the price of large cars would lead to diminished scrappage of large cars while small and medium car scrappage would be unaffected.

Vehicle Miles Traveled Estimator
Review of Recent Models

Several attempts have been made to identify the key factors affecting automobile vehicle-miles traveled (VMT). Summaries of five econometric studies* and a Federal Highway Administration

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* These are Chase Econometric Associates, Inc., The Effect of Tax and Regulatory Alternatives on Car Sales and Gasoline Consumption, submitted to the Council on Environmental Quality, May 1974; Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Draft Report, prepared for the Federal Energy Administration, Office of Energy Systems, Passenger Car Use of Gasoline: An Analysis of Policy Options, February 1975; The Rand Corporation, How to Cut Gasoline: Public Policy Alternatives for the Automobile, October 1974; and U. S. Department of Transportation, Transportation Systems Center, A Method for Projecting Aggregate Auto Miles Traveled, May 1975.

analysis* based on assumptions regarding several socio-economic conditions are presented. Included in each description of the econometric models is the respective estimating equation with its relevant statistical characteristics. Table 2-10 shows a comparison of the parameters used in each model. All of the studies include the effect of the fuel cost on driving by using either the price of gasoline, the fuel efficiency (MPG), or a ratio of the two. Another relatively common parameter was income, which appeared, in one form or another, in four of the models.

Transportation Systems Center (TSC) - The approach followed here is that projections of VMT should be sensitive to at least the price of gasoline and automobile fuel economy. VMT is estimated on a per-household basis rather than a nationwide aggregate since the former method produced coefficients that were statistically more significant. The estimating equation is:

$$V(t) = \underset{(3.84)}{1596} + \underset{(6.23)}{.823}V(t-1) + \underset{(2.87)}{2150}\frac{1}{G} + \underset{(2.53)}{.39168}\frac{P}{G} - \underset{(-5.75)}{142,585}\frac{P}{G}$$

$$(R^2 = .995)$$

* U. S. Department of Transportation, Federal Highway Administration, Highway Travel Forecasts, November 1979.

TABLE 2-50 - PARAMETERS USED IN MODELS OF FORECASTING AUTOMOBILE VEHICLE MILES TRAVELED

Parameters	Model				
	TSC	EIA	FEA	CHASE	RAND
Last Year's VMT	✓		✓		
Population (or Households)	✓		✓		
Number of Drivers	✓				
Income	✓	✓	✓	✓	
Price of Gasoline				✓	✓
Fuel Efficiency (MPG)					✓
Fuel Cost per Vehicle-Mile (Price of gas ÷ MPG)	✓	✓	✓		
Price of all Goods and Services				✓	
Price of New Cars				✓	
Total Automobile Stock				✓	✓
Unemployment Rate			✓		
Safety and Emissions Regulations					✓

Sources: Chase Econometric Associates, Inc., The Effect of Tax and Regulatory Alternatives on Car Sales and Gasoline Consumption, submitted to the Council on Environmental Quality, May 1974; Energy and Environmental Analysis, Inc., Gasoline Consumption Model, Draft Report, prepared for the Federal Energy Administration, May 1974; Federal Energy Administration, Office of Energy Systems, Passenger Car Use of Gasoline: An Analysis of Policy Options, February 1974; The Rand Corporation, Note to Hans Mayer: Public Policy Alternatives for the Automobile, October 1971; and U.S. Department of Transportation, Transportation Systems Center, A Method for Projecting Aggregate Auto Miles Traveled, May 1974.

where

V(t) = vehicle miles traveled per household in year t

D = number of drivers per household

R = real disposable income per household (1958 dollars)

P = real price of gasoline (1967 dollars/gallon)

E = average fleet fuel efficiency (miles per gallon)

Note that P/E represents the fuel cost of traveling one mile.

The number of drivers and income variables together act as a proxy for the stock of automobiles. Annual nationwide data from 1951 through 1974 are used for estimation.

Energy and Environmental Analysis, Inc. (EEA) - This research effort details several variables which are thought to influence VMT--disposal income, lagged automobile stock, fuel cost per mile of new cars and last year's automobile fleet, the cost per mile of other transit modes, the unemployment rate and demographic factors such as the age distribution of the population. However, the estimating equation presented includes only three of these parameters:

$$VMT = \underset{(8.4)}{.834} + \underset{(33)}{1.39}\,DI - \underset{(1.6)}{.3267}\,CV\ (new) - \underset{(3.2)}{.0615}\,CV\ (lagged\ stock)$$

$$(R^2 = .99)$$

where

DI = disposable income in 1958 dollars

CV (new) = average cost per VMT of new cars

CV (lagged stock) = cost per VMT of last year's fleet.

Federal Energy Administration (FEA) - This model forecasts VMT per capita as a function of per capita disposable income, the unemployment rate and the cost per mile of automobile travel. The estimated equation is:

$$\begin{aligned}
VMAUTO = N * EXP\ & \underset{(12.6830)}{(.80967} * LOG\ (VMAUTO\ (-1)/N(-1)) \\
& + \underset{(13.1275)}{6.5184} - \underset{(-17850)}{.35775} * LOG\ (COSTPM) \\
& + \underset{(11.1575)}{.97561} * LOG\ (YD58\$N) + \underset{(0.9352)}{.0026184} * RU \\
& = .80967 * (6.5184 - .35775 * LOG\ (COSTPM\ (-1)) \\
& + .97561 * LOG\ (YD58\$N(-1)) \\
& + .0026184 * RU(-1))
\end{aligned}$$

Adjusted R^2 = .9959

D-W = 1.1295

SSE = .01173

where:

VMAUTO = total vehicle-miles of passenger cars

N = total population

COSTPM = cost per mile of driving an automobile

YDS88N = disposable income per person in 1958 dollars

RU = unemployment rate

Chase Econometric Associates, Inc. - This model projects total VMT as a function of the automobile stock, an income variable, namely wages and salaries, and three price variables--average price of new cars, relative price of gasoline, and the change in the price of all goods and services. The estimated equation is:

$$VM = \underset{(9.2)}{78.5}\ CAR - \underset{(2.5)}{3944.5}\ PCIGO/PCI + \underset{(2.3)}{5181.0}\ \Delta\ PCI + \underset{(2.1)}{784.1}\ PUVNC_{-3} + \underset{(2.2)}{8.81}\ \Delta\ VW + 3416.1$$

$$R^2 = 0.996$$

$$Se = 100.2$$

$$DW = 1.39$$

where:

VM = motor vehicle travel of personal passenger vehicles, hundreds of millions of vehicle miles

CAR = total number of personal passenger vehicles registered, hundreds of thousands, R. L. Polk series as of July 1

PCIGO = consumer price index of gasoline and oil, 1967 = 100.0

PCI = consumer price index, all goods and services, 1967 = 100.0

PUVNC = unit value (average price) of new cars, thousands of dollars

YW = wages and salaries, billions of current dollars

The overall consumer price index acts as a proxy for the cost of competing services, while the average price of new cars is a proxy for gross vehicle weight and quality of cars--the rationale being that the more luxurious a recently purchased car is, the more likely an individual will use it for a long distance trip.

The Rand Corporation - This study first estimates VMT per household by regressing (logarithmically) travel on household automobile ownership, the index of real gasoline prices, and a dummy variable for Federal regulations regarding safety and emissions standards. However, a derived form of this equation is estimated which separates the effects on VMT of changes in gasoline price and changes in fuel efficiency. Both forms of these equations are shown below:

Estimated Form

$LM = 0.176 + 0.864051LA - 0.368531LP_g + 0.025430$

(753.59) (13.360) (3.520) (2.316)

D.F.:13 S.E.:0.01130 R^2:0.99 F:547.29 D-W:1.26

Derived Form

$LM = 7.996 + 0.864051LA - 0.444091LP_g + 0.4409LE + 0.035320$

where

M = automobile vehicle-miles per household

A = Automobile stock per household

G_g = CPI index of real gasoline prices

D = dummy variable for Federal regulations for safety and emissions

E = Average miles per gallon for the automobile fleet.

L = Indicates logarithmic value.

Annual data for the period 1956 to 1972 was used in the estimation process.

Federal Highway Administration - Three sets of VMT forecasts are made on the basis of several socio-economic factors. The first set of projections utilized various assumptions about

the number of drivers and the annual miles per driver for the different age groups of the population, and then summed the products to obtain total VMT. Alternative method of prediction was based on the number of households by car ownership category and the VMT per household by car ownership category. A third set of projections was made on the basis of various assumptions regarding vehicle mix, total fuel consumption, miles per gallon per vehicle, and the annual miles driven per vehicle.

Marketing and Mobility Model, VMT Estimator

The selection of the parameters to be included in the estimating equation of vehicle miles traveled (VMT) focused on two basic considerations: the general degree of predictability and the sensitivity to energy conservation legislation. Many variables have an effect on automobile travel, but some either have an unquantifiable historical record or possess a high degree of uncertainty for the future. Thus, they are excluded from the model. After careful review of the existing VMT models and our own econometric analysis, plus the understanding of specific inputs to be provided by other panels of the Task

Force, we have based the forecast of aggregate automobile travel on consumer income, total cars in use, the fuel cost of operating a vehicle, and the number of consumer spending units. This last category took the form of households due to our statistical experience and consistency with other sections of this report. Likewise, VMT, income, and the automobile stock were expressed on a per-household basis due to statistical considerations. The inclusions of policy-oriented variables, such as retail gasoline price and fuel economy, enable the model to be responsive to nearly all the potential energy-related measures enacted by the Congress. The estimated equation was as follows:

$$\frac{VMT}{HHLD} = \underset{(-3.65576)}{-52979.8} + \underset{(3.5243)}{15087}\ LOG\ \frac{DI}{(HHLD)} + \underset{(2.7471)}{6337.7}\ \frac{AUTOC}{HHLD} - \underset{(-2.7757)}{2204.24}\ CPM$$

$$R^2 = .9767$$

$$D\text{-}W\ Statistic = .4614$$

$$d.f. = 18$$

$$S.E.E. = 257.235$$

where

$\frac{VMT}{HHLD}$ = Annual VMT per household

$\frac{DI}{HHLD}$ = Real Disposable Income per household (1967 dollars)

AUTOS/HHLD = Total Cars in Use (as of January 1 of each year) per household

CPM = Index of the real fuel cost per mile (price of gasoline ÷ average fleet fuel economy, deflated by CPI, all items), where 1967 = 1.00.

The t-statistics, shown in parentheses, reveal that all variables are statistically significant at a 95 percent confidence internal. Total VMT was alternatively estimated as a function of disposable income, automobile stock and fuel cost, resulting in a slightly higher R^2 but a lower D-W statistic and the stock variable and constant being insignificant. Also, inclusion of households enables us to incorporate the effects of population trends in the analysis. Our low D-W statistic indicates the presence of serial correlation and excludes the use of a lagged dependent variable; the ordinary least square method of estimation would result in biased and inconsistent estimates. Also, regressions revealed perverse signs whenever the lagged dependent variable was included.

Annual data used in this analysis cover the years 1954 through 1973. Data on VMT and fleet miles per gallon originated from the Federal Highway administration's Highway Statistics. The

source for the nominal price of gasoline is Platts' Oil Price Handbook and Oilmanac, while cars in use figures were from R. L. Polk and Company, as published in Automotive News. The number of households is reported by the Bureau of the Census, disposable income comes from the Bureau of Economic Analysis, and the Consumer Price Index is published by the Bureau of Labor Statistics.

4.8 MODEL SUMMARY AND SENSITIVITY TESTS

In Table 4-51, the equations of the model are summarized as an inter-related system. The fleet model which is used to calculate fuel consumption and provide bookkeeping with respect to fleet composition is not shown. This is not an estimated or behavioral model. Rather, the fleet model is a set of identities that represent physical relationships, for example, the fact that the gas consumed by a vehicle is equal to the miles it travels divided by its fuel economy.

Sensitivity Analysis

The interrelated structure of the Marketing and Mobility Model does not lend itself to a direct interpretation of model parameters. The apparent generalized price elasticity in the automobile demand estimator is an example. As discussed above, the generalized price includes both the cost of purchasing and operating an automobile. In addition, the generalized price also influences scrappage, and scrappage is included as an independent variable in the automobile demand estimator. This feedback causes the true price elasticity of automobile demand

TABLE 2-51

MODEL SUMMARY

1) $N_t = (396,721.3)(0_t^* - (Autos_t - D_t))^{.2178}\ (R_t^*)^{-1.7039}$

2) $0_t^* = \left(\frac{1}{2}H_t P_{1t}\right)\ HHLD_t$

3) $H_t = .017861^{.4743}$

4a) $B_t = \frac{1}{1+e^{-(-4.1749 - 1.9660(R_t^B) + 3.5092(R_t^M) + 5.6428(B_{t-1}))}}$

4b) $M_t = \frac{1}{1+e^{-(-4.1749 - 2.0765(R_t^M) + 3.5450(R_t^B) + .2586(I_t^L) + 5.6428(M_{t-1}))}}$

4c) $L_t = \frac{1}{1+e^{-(-4.1749 - .4299(R_t^L) + 1.8117(R_t^M) + 5.6428(L_{t-1}))}}$

5) $SPO_t = .4089 - .0784(P_n)_t - 6.195(U_t)$

6) $\frac{V}{H} = -52079.8 + 15087\ LOG\ \frac{DI}{HHLD}_t + 2204.24(CNP)_t + 6337.24\ \frac{AUTOS}{HHLD}_t$

N_t = Total new car sales in year t

0_t^* = Target ownership of automobiles in year t

$(Autos)_t$ = The stock of automobiles on hand as of January 1 of year t

D_t = The number of automobiles scrapped during year t

R_t^* = An index of the real generalized price of new cars, 1967 = 1.00

B_t, M_t, L_t = Market shares of small, medium, and large cars, respectively, in year t

R_t^B, R_t^M, R_t^L = An index of the real generalized price of small, medium, and large cars, respectively, relative to that of all new cars in year t, 1967 = 1.00

SPO_t = The rate of scrappage in year t of vehicles eight or more years of age

$(P_n)_t$ = An index of the real price of new cars in year t 1967 = 1.00

U_t = The unemployment rate in year t

DI_t = Total real disposable income in year t

VMT_t = Total vehicle miles traveled in year t

CPM_t = An index of the fleet real gasoline costs per mile in year t, 1967 = 1.00

$HHLD_t$ = The total number of households existing in year t

P_{1t} = Fraction of total households in year t having income 1

to relate both to scrappage and to sales in a way which varies over time. In Table 2-52 the calculated automobile demand elasticity with respect to purchase price is displayed under different conditions in three years: 1976, 1980, and 1984. Since elasticities are not generally constant in the Marketing and Mobility Model, two sets are offered for two different levels of a price change in 1976 with constant prices thereafter. By maintaining ceteris paribus conditions in all other variables and by examining a one-time price change, the short term versus long term price elasticity can be known. Such simplified input conditions will not generally occur in model application.

TABLE 2-52

CALCULATED ELASTICITY OF AUTOMOBILE DEMAND WITH RESPECT TO THE PRICE OF AUTOMOBILES

Year	10 Percent Automobile Price Increase in 1976 - Constant Thereafter	25 Percent Automobile Price Increase in 1976 - Constant Thereafter
1976	= 1.161	= 1.242
1980	= 0.571	= 0.676
1984	= 0.446	= 0.536

Returning specifically to the data in Table 2-53, the short term automobile demand elasticity with respect to purchase price is approximately -1.2 and a stable long term value of approximately .4 is attained in about four or five years. This estimate is consistent with the research results reviewed in Section 2.7 ("Functional Forms and Interrelationship Between Equations," "Automobile Demand Estimator," "Review of Previous Models").

The average price of automobiles also has a significant impact on fuel consumption and automobile travel as shown in Tables 2-56 and 2-57. As one would expect, the impacts of fuel price on each are similar, differing only by the marginal differences in fleet fuel economy which will be discussed shortly. In both impacts--fuel and travel--the long term impact is substantially higher due to the time it takes for the flow of automobile sales changes to affect the total stock of automobiles.

In Table 2-55, the elasticity of automobile demand with respect to fuel price is shown under different conditions. These elasticity estimates are for the impact of fuel price changes on automobile demand, not fuel demand. Therefore, they should not

TABLE 2-53

CALCULATED ELASTICITY OF FUEL DEMAND
WITH RESPECT TO THE PRICE OF AUTOMOBILES

Year	10 Percent Automobile Price Increase in 1976-Constant Thereafter	25 Percent Automobile Price Increase in 1976-Constant Thereafter
1976	-0.043	-0.039
1980	-0.174	-0.195
1984	-0.238	-0.297

TABLE 2-54

CALCULATED ELASTICITY OF VEHICLE MILES TRAVELED DEMAND (VMT)
WITH RESPECT TO THE PRICE OF AUTOMOBILES

Year	10 Percent Automobile Price Increase in 1976 - Constant Thereafter	25 Percent Automobile Price Increase in 1976 - Constant Thereafter
1976	-0.067	-0.066
1980	-0.209	-0.223
1984	-0.259	-0.286

TABLE 3-55

CALCULATED ELASTICITY OF AUTOMOBILE DEMAND
WITH RESPECT TO FUEL PRICE

Year	10 Percent Fuel Price Increase in 1975 - Constant Thereafter	25 Percent Fuel Price Increase in 1975 - Constant Thereafter
1975	-0.614	-0.614
1980	-0.266	-0.307
1984	-0.211	-0.245

TABLE 2-56

CALCULATED ELASTICITY OF FUEL CONSUMPTION WITH RESPECT TO FUEL PRICE

Year	10 Percent Price Increase of Fuel in 1976 - Constant Thereafter	25 Percent Price Increase of Fuel in 1976 - Constant Thereafter
1976	-0.092	-0.092
1980	-0.202	-0.175
1984	-0.199	-0.215

TABLE 2-57

CALCULATED ELASTICITY OF VEHICLE MILES TRAVELED (VMT) DEMAND WITH RESPECT TO THE PRICE OF FUEL

Year	10 Percent Price Increase of Fuel in 1976 - Constant Thereafter	25 Percent Price Increase of Fuel in 1976 - Constant Thereafter
1976	-0.106	-0.107
1980	-0.177	-0.188
1984	-0.184	-0.211

be compared to the more often cited price elasticity of gasoline estimates. In Table 2-55 a fairly substantial first year automobile demand impact of -.6 (elasticity) is indicated for a fuel price change. This impact diminishes to around -.3 in 1980 and -.2 in 1984.

Fuel price elasticities in 1976, 1980, and 1984 are shown in Table 2-56. However, they are not comparable to most other estimates of the short and long term elasticities in the following sense: automobile fuel efficiency is held constant with respect to the base case when calculating these elasticities. Since automobile efficiency changes are insignificant in the short term (one to two years) insofar as total fuel consumption is concerned, the 1976 fuel price elasticity value in Table 2-54 is comparable to other short term estimates. At just under -.1, it is consistent with the large body of research regarding this elasticity. This reflects the immediate impact of driving less and, as is shown in Table 2-57, the elasticity of VMT demand with respect to fuel is similar at -.1. This estimate (for VMT) is slightly higher than the price elasticity of fuel demand due to the sales impact of the higher fuel prices on 1976 automobiles

(Table 3-55). The 1976 automobiles, having higher fuel economy, contribute to a more efficient fleet. In the longer term, however, the tendency to shift to smaller cars precipitated by a fuel price increase causes the fuel consumption elasticity with respect to fuel price to be generally higher than the VMT demand elasticity with respect to fuel price. But the continued automobile sales impact of the fuel price increase causes the fleet fuel economy to increase substantially less than if the technical efficiency of automobiles was not held constant. Since technical efficiency is exogenous to the model structure, the full long term impact of a fuel price change on fuel consumption is not included in the "long term" fuel price elasticity of about -.2 shown in Table 3-57. The substantially higher estimate by Wildhorn, et al (64) is not necessarily inconsistent with this result since technical fuel efficiency shifts were implicitly estimated in the Rand HAV model. The Marketing and Mobility Model could be used explicitly to estimate these technical shifts in the context of a supply and demand analysis which considers the cost of improving the technical efficiency of automobiles (for example see reference 15). However, in the context of the Motor Vehicle Goals Study the separate scenarios fix the technical efficiency of each sub-class of automobile at predetermined levels independently of all variables which

are endogenous to the Marketing and Mobility Model.

The elasticity characteristics of the market share estimator are not at all apparent from its parameter estimates. The remaining elasticity calculations directly involve the market share estimator and provide insight regarding its behavior. In Table 2-58 the elasticity of total automobile demand with respect to the price of small, mid-size, and large cars is shown. Total demand is most sensitive to the price of large cars which reflects the importance of large cars as a proportion of total demand. The short term automobile demand elasticity (with respect to large car prices) is about -.7 dropping to -.2 in 1984. The other classes start with smaller short term elasticities but reach essentially the same long term estimate of -.15 to -.21. The initial impact, therefore, of large car price changes in the total market is substantially stronger than for mid-size or small car price changes, but within four years, all price changes approach similar, smaller levels.

All elasticities in Table 2-58 are consistent with economic theory since any price increase in a class, ceteris paribus, must logically diminish total demand. The only apparent surprise in Table 2-58

Year	10 Percent Interest Rate	15 Percent Interest Rate	20 Percent Interest Rate	25 Percent Interest Rate	30 Percent Interest Rate
1968	$-0.13	$-0.13	$-0.13	$-0.13	$-0.13
1969	$-0.23	$-0.23	$-0.23	$-0.23	$-0.23
1970	$-0.33	$-0.33	$-0.33	$-0.33	$-0.33
1971	$-0.43	$-0.43	$-0.43	$-0.43	$-0.43
1972	$-0.53	$-0.53	$-0.53	$-0.53	$-0.53
1973	$-0.63	$-0.63	$-0.63	$-0.63	$-0.63
1974	$-0.73	$-0.73	$-0.73	$-0.73	$-0.73
1975	$-0.83	$-0.83	$-0.83	$-0.83	$-0.83
1976	$-0.93	$-0.93	$-0.93	$-0.93	$-0.93
1977	$-1.03	$-1.03	$-1.03	$-1.03	$-1.03
1978	$-1.13	$-1.13	$-1.13	$-1.13	$-1.13
1979	$-1.23	$-1.23	$-1.23	$-1.23	$-1.23
1980	$-1.33	$-1.33	$-1.33	$-1.33	$-1.33
1981	$-1.43	$-1.43	$-1.43	$-1.43	$-1.43
1982	$-1.53	$-1.53	$-1.53	$-1.53	$-1.53
1983	$-1.63	$-1.63	$-1.63	$-1.63	$-1.63
1984	$-1.73	$-1.73	$-1.73	$-1.73	$-1.73
1985	$-1.83	$-1.83	$-1.83	$-1.83	$-1.83
1986	$-1.93	$-1.93	$-1.93	$-1.93	$-1.93
1987	$-2.03	$-2.03	$-2.03	$-2.03	$-2.03
1988	$-2.13	$-2.13	$-2.13	$-2.13	$-2.13
1989	$-2.23	$-2.23	$-2.23	$-2.23	$-2.23
1990	$-2.33	$-2.33	$-2.33	$-2.33	$-2.33
1991	$-2.43	$-2.43	$-2.43	$-2.43	$-2.43
1992	$-2.53	$-2.53	$-2.53	$-2.53	$-2.53
1993	$-2.63	$-2.63	$-2.63	$-2.63	$-2.63
1994	$-2.73	$-2.73	$-2.73	$-2.73	$-2.73
1995	$-2.83	$-2.83	$-2.83	$-2.83	$-2.83
1996	$-2.93	$-2.93	$-2.93	$-2.93	$-2.93
1997	$-3.03	$-3.03	$-3.03	$-3.03	$-3.03
1998	$-3.13	$-3.13	$-3.13	$-3.13	$-3.13

is the fact that, notwithstanding the large proportion of total demand that large cars represent in the base case, the demand elasticity of large cars is usually thought to be relatively inelastic. The relatively large short term impact on total sales might therefore be unexpected. However, as Tables 2-59 through 2-61 reveal, the share elasticity of large cars with respect to large car prices (Table 2-61) is substantially smaller than the share elasticity of mid-size cars with respect to mid-size car prices (Table 2-60) or the share elasticity of small cars with respect to small car prices. This apparent discrepancy is explained by the relatively low cross-share elasticities for large car prices (Tables 2-59 and 2-60). Consequently, relatively few purchasers who do not buy a large car because of a large car price increase switch to the mid-size and small cars. However, purchasers of small or mid-size cars who face price increases in either class are more ready to accept the other class as a substitute purchase. Thus, while the demand elasticity of small or mid-size cars is high relative to large cars, a price increase in either class alone does not depress total automobile sales as would a price increase in large cars.

| | | |

TABLE I-60

CALCULATED ELASTICITY OF MID-SIZE CAR MARKET SHARE WITH RESPECT TO THE PRICE OF SMALL CARS, MID-SIZE CARS, AND LARGE CARS

Year	10 Percent Price Increase of Small Cars in 1976 - Constant Thereafter	25 Percent Price Increase of Small Cars in 1976 - Constant Thereafter	10 Percent Price Increase of Mid-Size Cars in 1976 - Constant Thereafter	25 Percent Price Increase of Mid-Size Cars in 1976 - Constant Thereafter	10 Percent Price Increase of Large Cars in 1976 - Constant Thereafter	25 Percent Price Increase of Large Cars in 1976 - Constant Thereafter
1976	1.95	1.90	- 2.34	- 3.40	0.23	0.24
1980	3.34	3.12	- 4.01	- 5.32	0.45	0.47
1984	3.38	3.16	- 4.09	- 5.36	0.47	0.50

[redacted]

[redacted]

[redacted]

The only anomaly in the share elasticity estimates presented in Tables 2-59, 2-60, and 2-61 occurs in Table 2-61. The share elasticities of large cars with respect to small car prices have negative signs in four of the six observations. The other two observations are exactly zero. However, these six elasticity estimates are insignificantly different than zero and appear to be caused by the normalization process which adjusts shares to sum to one. This part of Table 2-61 should be interpreted as indicating that small car demand is essentially unaffected by large car prices.

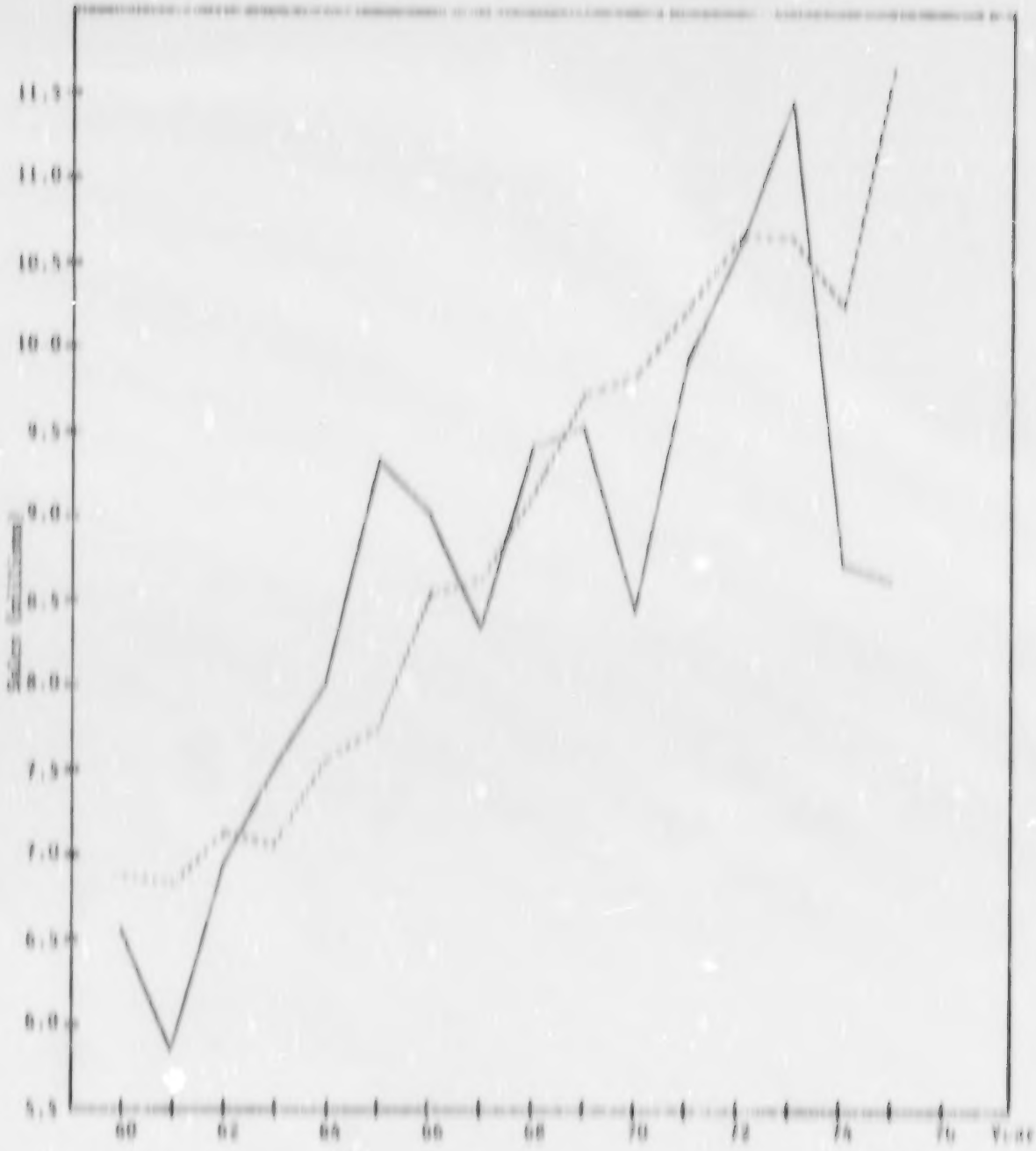
Model Performance

While long run forecasting models cannot be adequately evaluated simply on their performance in estimating past data, such "back-casts" can provide a general indication of how well a model fits the data upon which it was estimated. Since the Marketing and Mobility Model was calibrated with data through 1973, observation for 1974 and 1975 provide an opportunity to evaluate forecasting performance. However, since the model was not designed to be sensitive to short term exogenous variables, 1974 and 1975 data provide only a limited basis for evaluation of the model's performance beyond 1980 since the recession apparent in these years is presumably not typical of average conditions.

New Car Sales

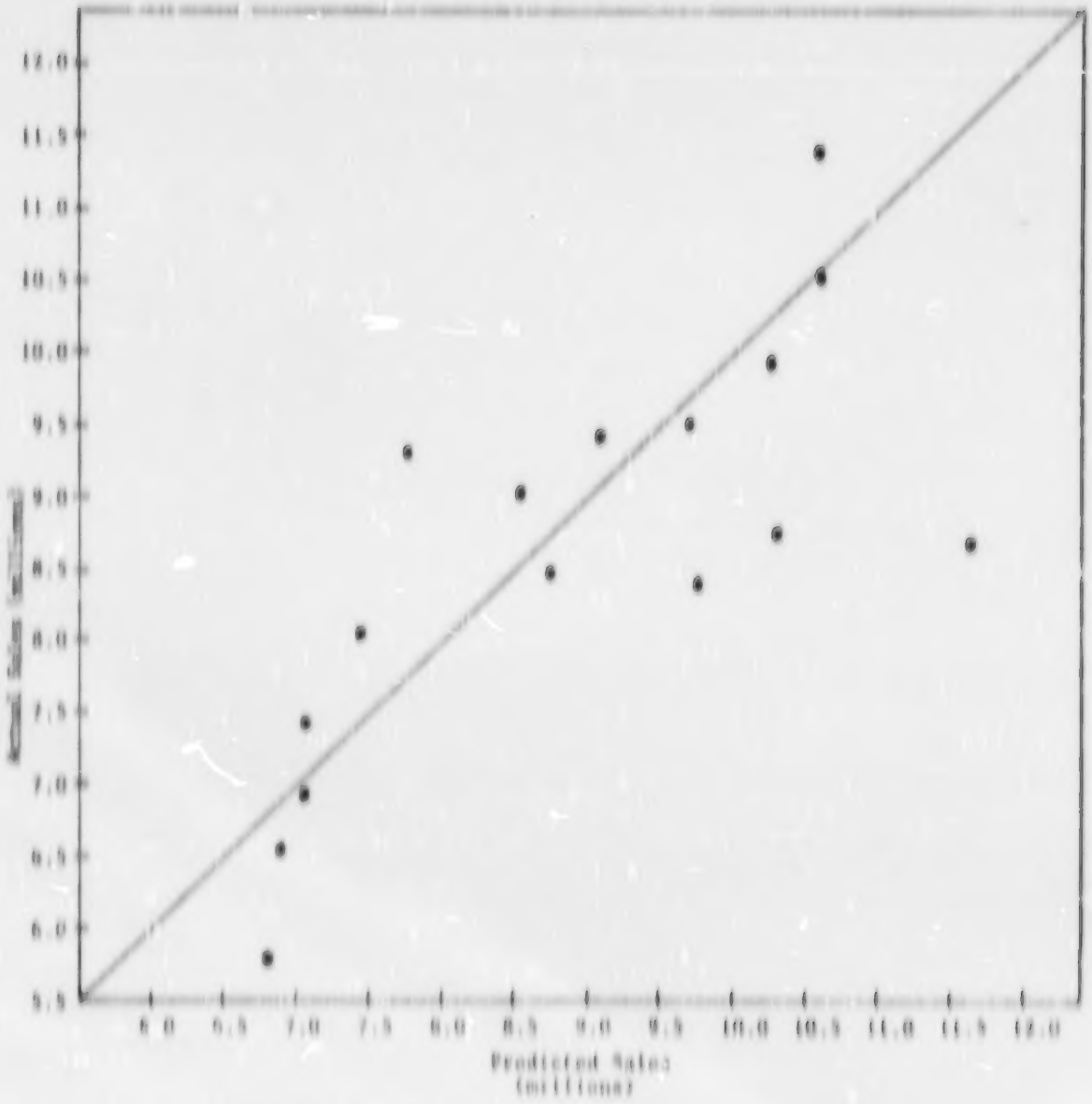
The historical pattern of automobile sales is characterised by substantial year to year fluctuations as is shown in Figure 2-9. The predicted automobile sales follow the same general trend of actual sales but fluctuates rather less than do actual sales. This particularly reflects the absence of short term variables within the Marketing and Mobility panel model structure (e.g., credit availability) which are essentially unavailable for long term forecasts. Further, short term fluctuations are also likely to be attributable to several non-quantifiable factors (success of styling, etc.). The severe drop of automobile sales in 1974 and 1975 is probably largely due to uncertainties precipitated by the energy "crisis" and to the severe recession during those years. The automobile demand estimator did not track the 1974 and 1975 dip but its 1976 forecast is much closer to various estimates of 1976 sales that have been recently made.

In Figure 2-10, the pattern of observed versus predicted annual automobile sales is shown. The observations which lie close to the 45° line indicate a relatively accurate prediction for each year.



Source: Automotive News, Almanac Issue 1975.

FIGURE 2-9: NEW CAR SALES: MODEL PREDICTION COMPARED TO HISTORIC EXPERIENCE BY YEAR (1960-1975)



Source: Automotive News, Almanac Issue 1975.

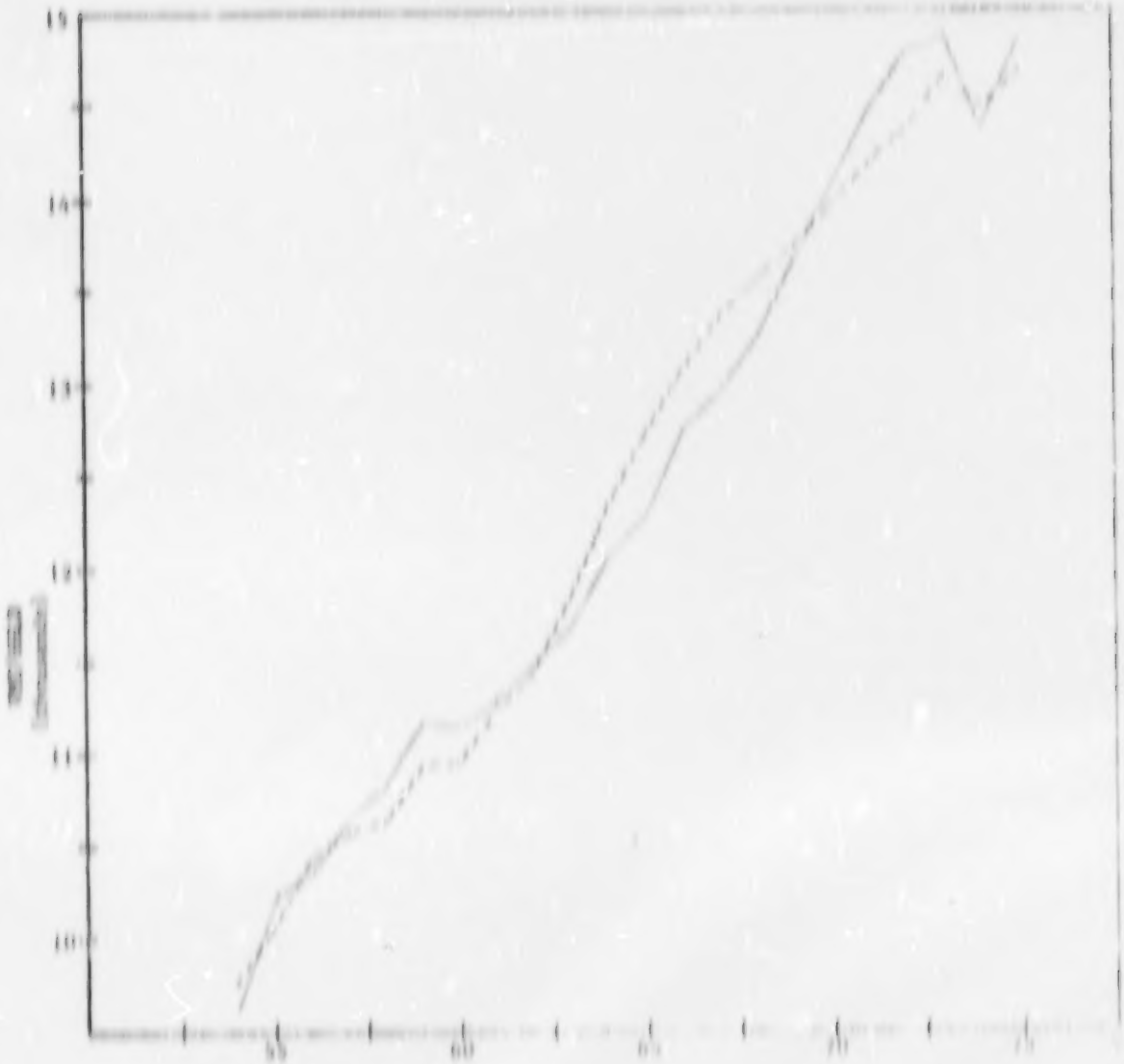
FIGURE 2-10: NEW CAR SALES: PREDICTIONS COMPARED TO HISTORIC EXPERIENCE

Vehicle Miles Traveled

Unlike automobile sales, the demand for automobile travel (VMT/household) displays a much more stable growth pattern. Automobile travel demand (like gasoline demand) is largely insulated from rapid shifts in new car sales since new vehicles represent only a small fraction of the automobile fleet for any given year. This is apparent in Figure 2-11. Also apparent is the more successful relationship between forecasted VMT/hhd and observed VMT hhd both in Figure 2-11 and the observed versus predicted display of Figure 2-12. In particular, the travel decline of 1974 and reestablishment of 1973 travel levels in 1975 were predicted quite closely.

Market Share Forecasts

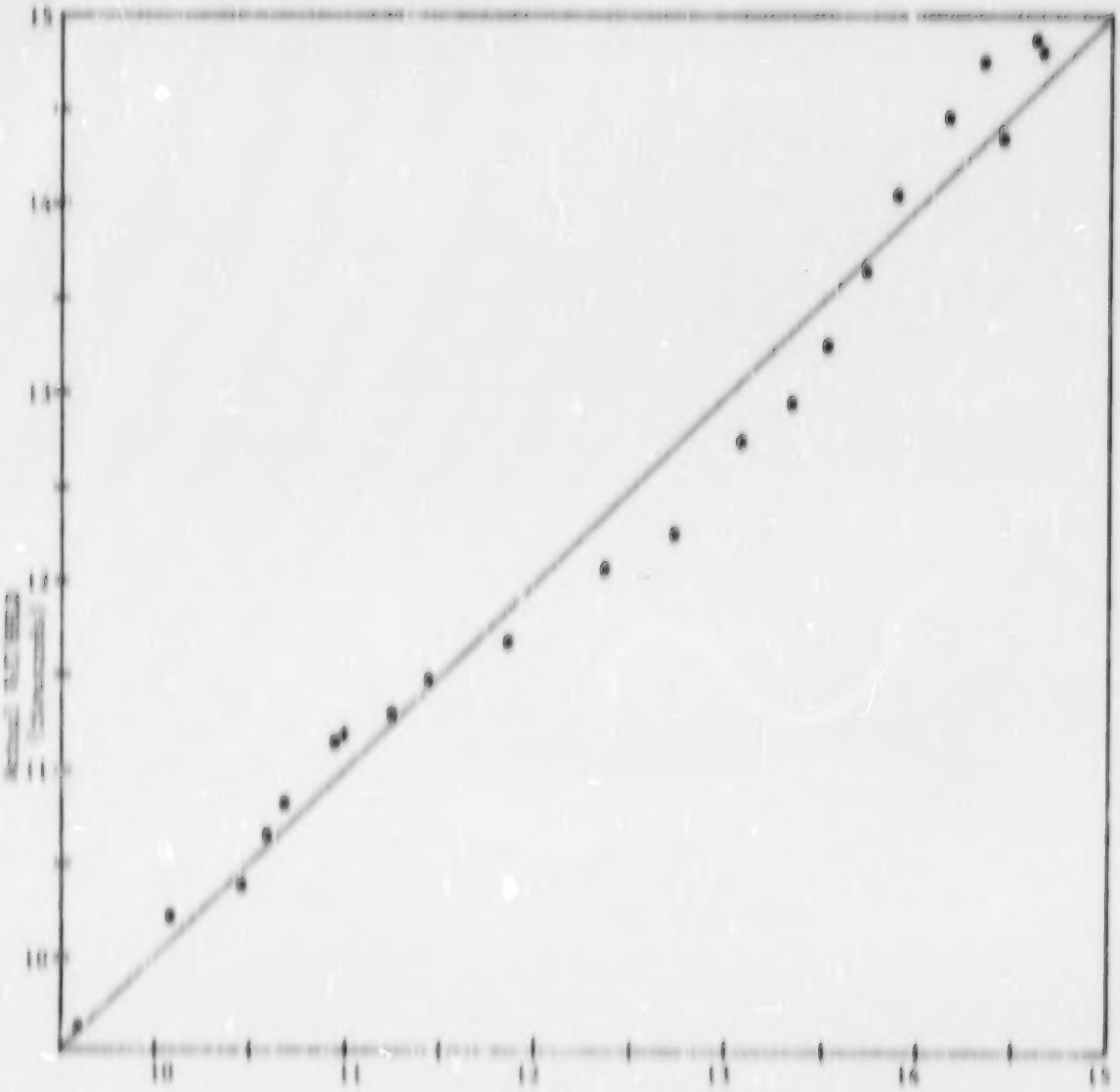
The market shares estimator is a key ingredient in the Marketing and Mobility Model. This model component is essential in computing important variables such as the sales-weighted fuel economy of new cars. From the standpoint of existing research, the market shares estimator is probably the most substantive contribution which the model presented here makes to the literature on automobile demand forecasting. This literature contains very few models of market share demand (see references 11, 12, and 19). Of these



Actual
Predicted

Source: Automotive News, Almanac Issue (1973); U. S. Department of Commerce, Survey of Current Business (Various Years).

FIGURE 2-11: VEHICLE MILES OF TRAVEL PER HOUSEHOLD: MODEL PREDICTIONS COMPARED TO HISTORICAL EXPERIENCE, BY YEAR (1955-1973)



Sources: Automotive News, Almanac Issue (1975); U. S. Department of Commerce, Current Population Reports, series P-25.

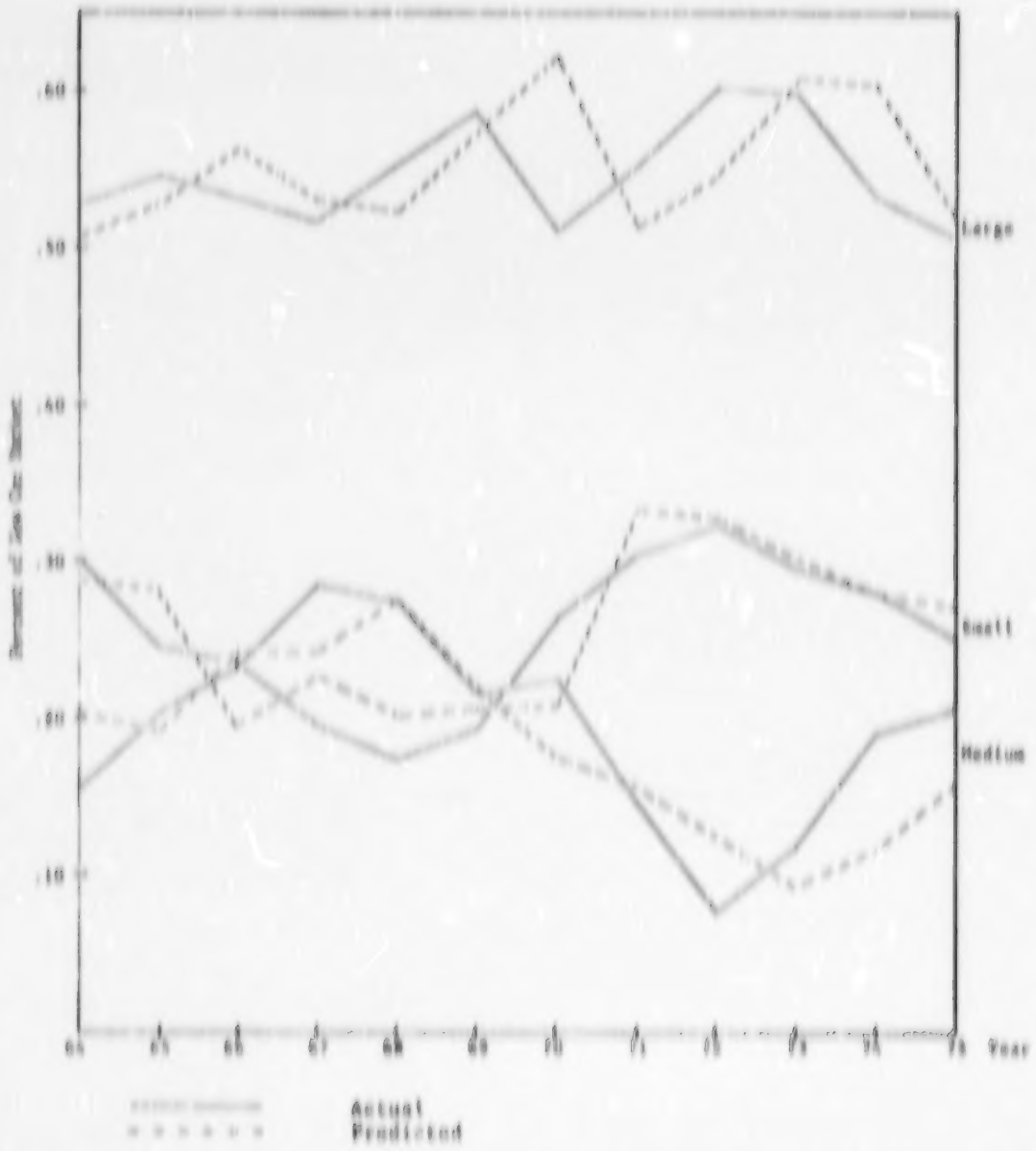
FIGURE 2-12: VEHICLE MILES OF TRAVEL PER HOUSEHOLD: MODEL RESULTS COMPARED TO HISTORIC EXPERIENCE

alternative models of market share, none have identified a complete set of "own" and "cross" price elasticities within and between market classes. Also, the logit probability model structure used here distinguishes this model from other available market share models which usually employ linear or log-linear formulations.

The actual and estimated market shares for small, mid-size, and large cars are shown in Figure 2-13. Estimated values track actual values in all years rather well, especially considering the volitility of the actual market shares. In particular, the "forecast" years 1974 and 1975 are estimated accurately with the substantial increase in mid-size car shares, drop in large car shares and slight decline of small car shares anticipated by the shares model. In Figure 2-14, the actual versus estimated values lie closely about the 45° line.

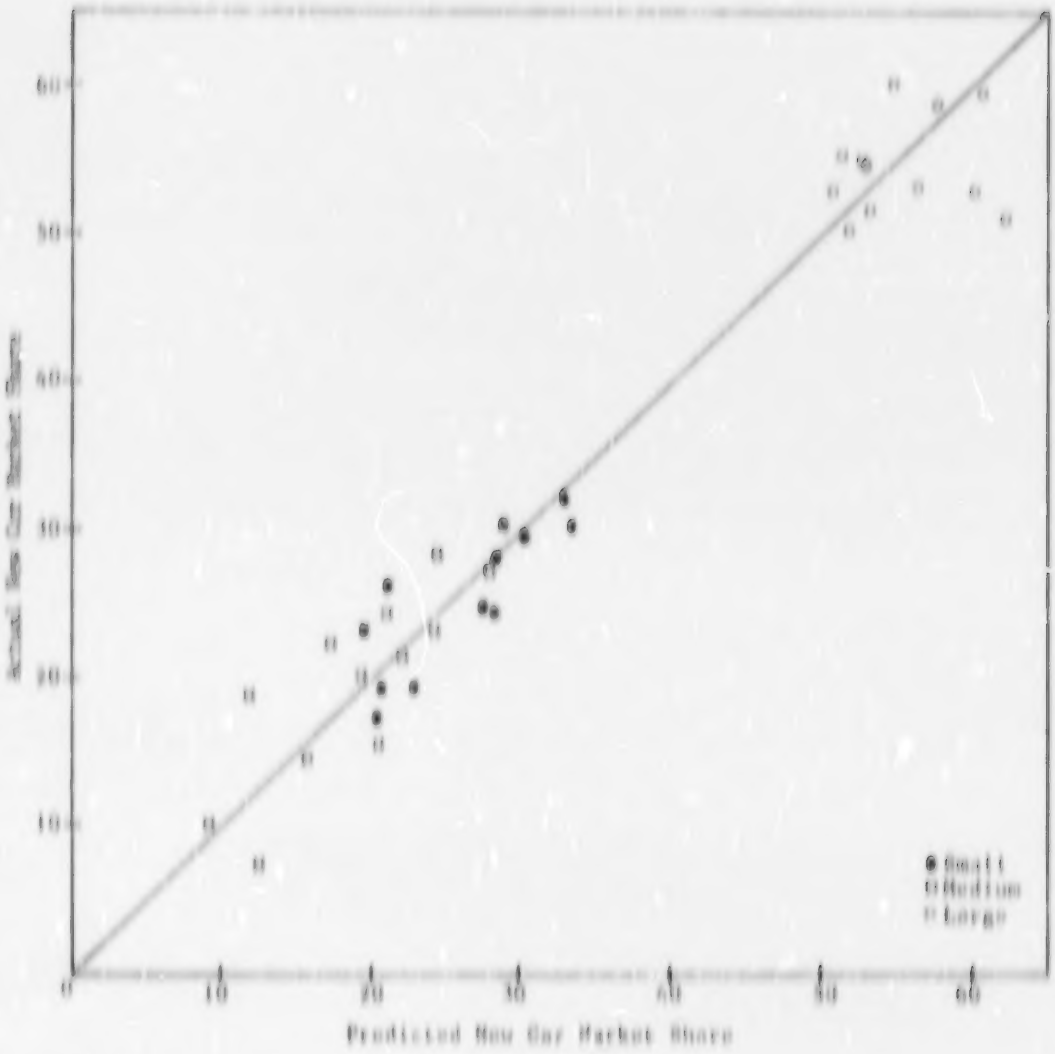
Summary

The foregoing sensitivity analysis and review of model performance provides an insight as to the behavior of the Marketing and Mobility Model which is not apparent from the model equations and their statistics (t- values, R^2s, etc.). The impact estimates of key variables such as automobile price and



Source: Computed from Automotive News, various Almanac Issues.

FIGURE 2-13: NEW CAR MARKET SHARES: MODEL PREDICTIONS COMPARED TO HISTORICAL EXPERIENCE BY YEAR (1966-1975)



Source: Computed from Automotive News, various Almanac issues.

FIGURE 2-14: NEW CAR MARKET SHARES: MODEL PREDICTIONS COMPARED TO HISTORIC EXPERIENCE

fuel price is consistent with the substantial existing body of research when direct comparisons are possible (e.g., the price elasticity of gasoline demand). When alternative estimates are not generally available (e.g., the shares sub-model), the model behavior is consistent with *a priori* constraints that must necessarily be met. In particular, the shares model confirms expectations that large car share demand is relatively inelastic and that large cars are not good substitutes relative to other classes while small and mid-size cars are relatively close substitutes for each other.

The purpose of the Marketing and Mobility Model is to facilitate the comparison among alternate technological scenarios in the Motor Vehicle Goals Study. The absolute forecast of automobile and travel demand beyond 1980 and 1990 is not intended to be an exact projection of what can be expected close to the turn of the century. However, individuals in the distant future are probably going to display similar relative reactions to changes in travel costs as they do today. Consequently, if the availability of more fuel efficient cars today will precipitate more miles traveled today, it is likely to also have this effect in the future. By accounting for this

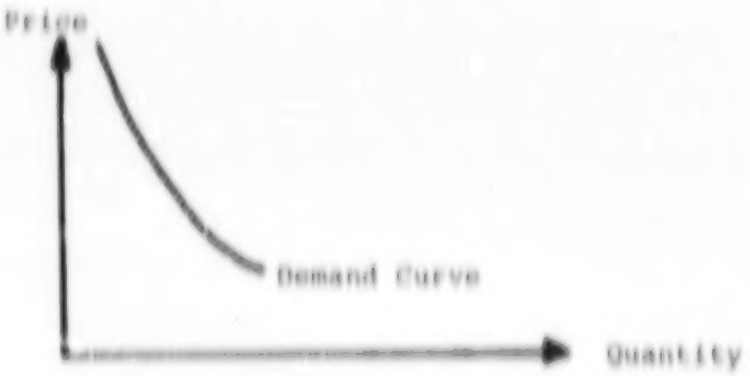
likelihood, it is unnecessary to assume that all technical scenarios will result in the same miles traveled independent of the fuel economy implicit in each scenario. A lowered cost of driving implied by a scenario will result in more miles traveled for that scenario which will mitigate some of the fuel savings associated with better fuel economy. Likewise, price increases for fuel efficient new cars will result in decreased scrappage of existing cars, also mitigating fuel savings. Without a behavioral model, vehicle survival rates would necessarily be assumed constant and the expected impact that increased new car prices have on scrappage would be left unaccounted for. The list of examples could be extended to discuss every endogenous variable in the Marketing and Mobility Model.

The forecasts of travel and automobile demand resulting from the Marketing and Mobility Model are included in the Report of the Interagency Task Force for Motor Vehicle Goals Beyond 1980.

GLOSSARY

demand function: The demand function is a relationship between the demand for some commodity or service and one or more demand influencing variables. The most ubiquitous demand influencing variable is price and often demand is stated simply as a function of price. However, other variables, besides price, can also be included in a demand function. Regardless of how many variables a demand function possesses, the relationship between any one of them and demand can be graphed by holding the values of all others constant. This relationship is often called the demand curve, especially when price is the variable being graphed as illustrated in Figure G-1.

FIGURE G-1



The price-quantity demand curve (which need not be curved) is usually downward sloping indicating more demand as price decreases.

elasticity: Elasticity is a measure of the sensitivity of demand with respect to changes in a variable which influences demand. If this variable is price the elasticity is called a price elasticity. For example, a price elasticity

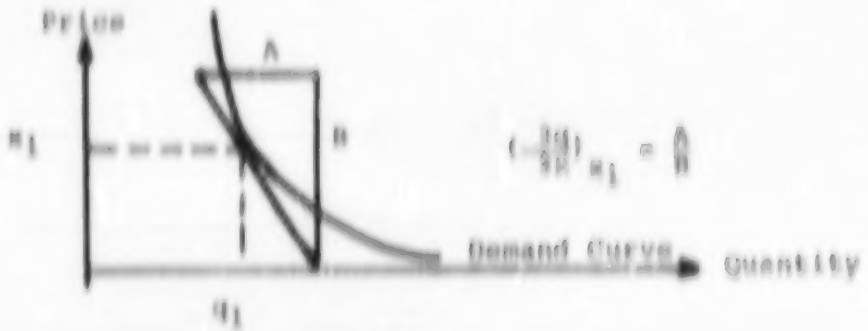
of -1 implies that a one percent reduction of a commodity price will result in a one percent increase in the demand for that commodity. There are, however, three distinct ways elasticity can be measured.

point elasticity: A point elasticity measures the instantaneous proportional rate of change between demand and a demand influencing variable at a specific point on the demand curve. The definition of point elasticity requires that the demand curve be differentiable around the specific point at which it is calculated. For any demand influencing variable x and demand variable q, point elasticity is defined,

$$\left(\frac{\partial q}{\partial x}\right)_{x_1} \quad \frac{x_1}{q_1}$$

where x_1 and q_1 are the ordinates of the point in question (see Figure G-2).

FIGURE G-2

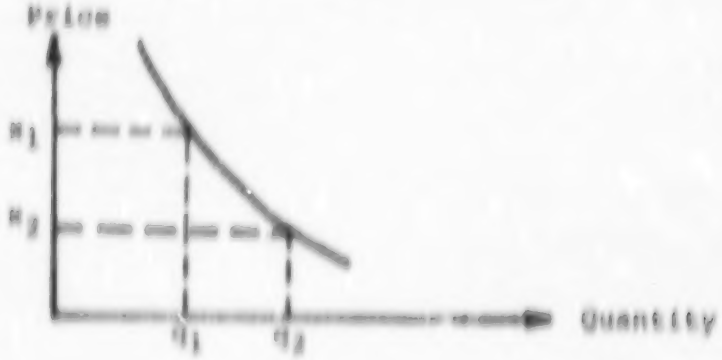


shrinkage ratio: A shrinkage ratio is the proportional change in demand resulting from a given change in a demand influencing variable. Two points on the demand curve are involved (see Figure G-3). Assume that at time period 1, demand = q_1 and price = x_1. Assume a price increase to x_2 with a resultant decrease of demand to q_2. The shrinkage ratio is defined as,

$$\frac{\frac{q_2 - q_1}{q_1}}{\frac{p_2 - p_1}{p_1}} = \frac{\Delta q}{\Delta p} \cdot \frac{p_1}{q_1}$$

where p_1 and q_1 are the price and demand levels before the change in price.

FIGURE G-1



arc elasticity: An arc elasticity is also calculated from two points on the demand curve (see Figure G-1). It is defined as,

$$\frac{\log q_1 - \log q_2}{\log p_1 - \log p_2} = \frac{\Delta \log q}{\Delta \log p}$$

The arc elasticity is often preferred to the shrinkage ratio since it comes much closer to preserving an important property of the point elasticity. That is, when the point price elasticity is equal to -1, gross revenue is maximized. When the point elasticity is numerically greater than unity, gross

revenues may be increased by reducing price and similarly, when the point elasticity is numerically less than unity, gross revenues may be increased by increasing price. This relationship does not hold true for the shrinkage ratio unless Δx approaches zero. However, this revenue maximizing relationship is approximately true for the arc elasticity under all conditions. Consequently, when elasticities need to be determined from discontinuous data, without the benefit of a fitted demand function, the arc elasticity provides the best estimate of the revenue implications of price changes.

sign of elasticity: As defined above, for the normal downward sloping relationship between price and quantity demanded, price elasticities have negative values. The more sensitive demand is to price, the more negative the elasticity will be.

cross elasticity: The cross elasticity is a measure of the sensitivity of demand for one commodity with respect to changes in the price or other characteristics of another commodity. For example, consider the demand for automobile trips and bus trips. If the demand function for automobile trips includes the price of transit trips (fare), a cross elasticity can be calculated between automobile trip demand and transit fare. The sign of this cross elasticity should be positive since an increase in transit fare would imply more automobile trips while simultaneously reducing the demand for transit trips.

income elasticity: Income elasticity is a measure of the sensitivity of demand with respect to changes in income. Such an elasticity implies that the income of the consuming group or individual is included as one of the demand influencing variables in the demand function. Income elasticity can either be positive, negative, or zero. A good which has a negative income elasticity is called an inferior good. As income increases, an individual will spend less on inferior goods and rather purchase more desirable substitutes.

endogenous variable:* A variable is endogenous with respect to a particular model or system of equations if it is determined within that system.

exogenous variable:* A variable is exogenous with respect to a particular model or system of equations if it is determined outside that system.

* These definitions are insufficient to determine whether variables are, in fact, endogenous or exogenous with respect to a particular system of equations. An exogenous variable must be statistically independent of the "disturbance" term in each equation. See Carl F. Christ, Econometric Models and Methods (New York, John Wiley, 1966, pp 357-361, for an exact definition of "exogenous."

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